Landscape Beneath the Waves

The archaeological investigation of underwater landscapes

Caroline Wickham-Jones

STUDYING SCIENTIFIC ARCHAEOLOGY 4

Landscape Beneath the Waves

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Landscape Beneath the Waves: the archaeological investigation of underwater landscapes

Caroline Wickham-Jones

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Front cover: A partially submerged Lycian sarcophagus at Kekova, the site of ancient Simena, southeast Turkey. Image: Özdoğan Archive.
Back cover: Left: Divers undertaking investigation and coring of the seabed. Image: Richard Bates, University of St Andrews. Right: Coring in the Bay of Firth, Orkney. Image: Richard Bates, University of St Andrews

The author during fieldwork in Orkney. Her original archaeological training did not prepare her for the necessity of immersion suits such as this (note the snow on the hills in the background)

I would like to dedicate this book, with thanks, to all those who taught me
archaeology in the 1970s:
Stuart Piggott;
Trevor Watkins;
Roger Mercer;
David Clarke.
How the world has changed.

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This book has been a long time coming and I must first of all thank my publishers, and especially Mike Allen and Julie Gardiner, for their forbearance and patience. Secondly, I would like to thank those who, knowingly and unknowingly, have helped me on my journey to explore the submerged landscapes of the world. So many wet and windy afternoons trying to take sediment cores, so many evenings spent discussing the minutiae of a seismic profile, so much time spent worrying about what it all means in human terms. In particular the Rising Tide Project research team: Martin Bates; Richard Bates; Ali Dawson; Sue Dawson; Dei Huws; and Nigel Nayling have all provided much explanation, helped out with illustrations, put up with lengthy discussion, not to mention my avoidance of bog-hopping.

John Howe and his team from the Scottish Association for Marine Science brought Freya the AUV to Orkney for her first (and hopefully not last) visit. Mark Edmonds guided me into my conclusions (over a nice bottle of red wine). Leo Sucharyna Thomas sprang into action to help out with a high-resolution ABM image (Plate 23). Denis Bates gave much last-minute help with other figures. Nic Flemming (besides being inspirational and encouraging), gave me the idea for Figure 2. Richard Bates, Ann Clarke, Sue Dawson, Ali Dawson, Jen Harland, Jill Harden, and Terry O'Connor all kindly acted as guinea pigs and read through the text – many thanks for your patience and helpful comments. Liz Gilmore kindly applied her eagle eye to spotting my many inconsistencies and errors.

Several of the smaller case studies and examples cited in the volume relate to the Rising Tide Project in Orkney. This multi-authored and interdisciplinary project is the research with which I have been personally involved in recent years, so that it has provided an easy source of photos and material (though I have made sure that a wide range of material from around the UK and elsewhere has also been used). Since the end of the last Ice Age, relative sea-level around the archipelago of Orkney, in the north of Scotland, has been rising, with the result that a considerable submerged landscape exists around the islands. As this period of rising relative sea-level coincides with the timespan of human settlement, the Rising Tide Project was set up in 2005 with the aim of quantifying landscape inundation around the islands and investigating the impact of this on both the prehistoric communities who lived there and the understanding and management of the archaeological resource today. This work has been funded by a mix

of private and research grants and, in this way, it has been possible to tailor research so that different aspects of the objectives could be studied as knowledge was acquired. Though the waters around Orkney are known for their high energy potential meaning that archaeological preservation might be considered minimal, in practice numerous sheltered bays and inlets mean that there is considerable scope for investigation. For this flexibility of research, I would like, in particular, to thank Historic Environment Scotland, The Leverhulme Trust (whose assistance allowed valuable time to research and reflect), Crown Estates Marine Stewardship Fund, NGS Waitt Trust, Carnegie Trust, the Royal Archaeological Institute, The Russell Trust, Scapa Flow Landscape Partnership and the Heritage Lottery Fund, Orkney Islands Council, Orkney Archaeology Society and the Society of Antiquaries of Scotland, as well as various private contributions.

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Where no credit is recorded the photos are the author's own.

If I have inadvertently left anyone out, I apologise.

As ever Rhona Jenkins proved expert at interpreting my garbled scribbles into clear drawings.

1. The archaeological exploration of underwater landscapes: Introduction

Once upon a time the world was a very different place. At the end of the last great Ice Age, sea-level around the world was lower and this meant that around the globe there was a less watery landscape. Coastal lands stretched further, and the continents were bigger (Fig. 1.1), in some cases landmasses were joined by dry land that has now disappeared beneath the waves. This state of affairs stretched far back into human history. It had a profound effect on the world as people knew it and it should, thus, influence the way in which we undertake research on the communities of early prehistory. For various reasons,

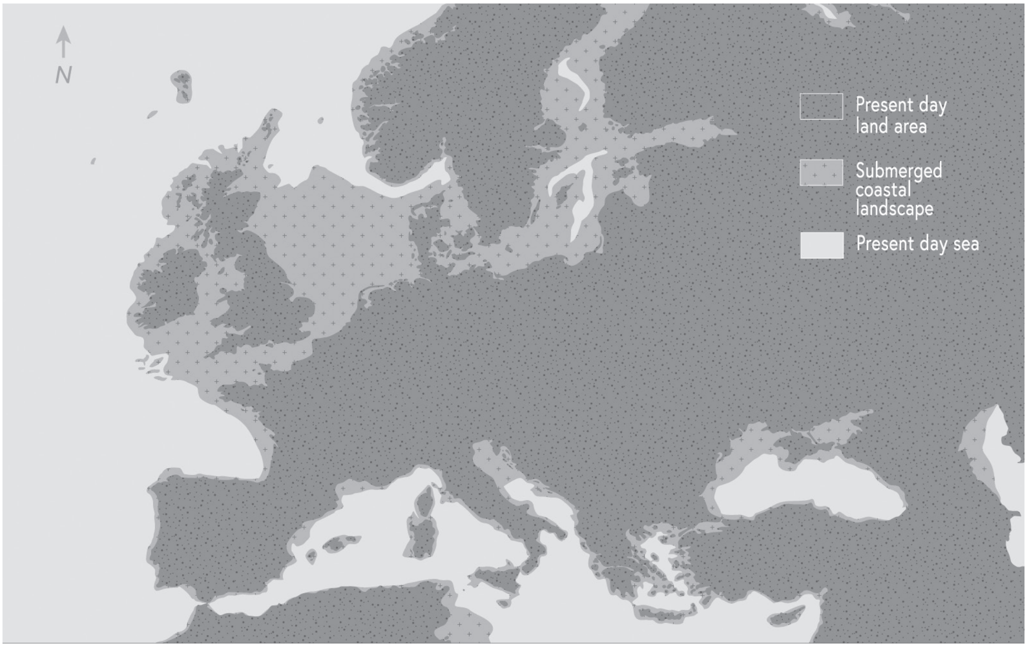


Fig. 1.1 Twenty thousand years ago relative sea-level around the world was considerably lower than today, thus changing the shape of the world as our ancestors experienced it. This figure gives an impression of the extent of dry land that has since been submerged around the European coasts. Image: Rhona Jenkins

this has not happened – mainly because of the difficulty of accessing and obtaining data from landscapes that now lie underwater. In recent decades, however, the development of new technology has opened the possibility of accessing this hidden world, a landscape that has hitherto been hidden. This means that the time has come to change the way we look at things. If we continue to base our understanding of past human communities on information drawn solely from the land, we are biasing the picture as surely as if we never studied the uplands, or only based our archaeology in urban areas.

No self-respecting archaeologist would consider such a narrow viewpoint to be valid, and yet it has taken a while for the importance of the underwater zone to permeate current narratives. This is largely due to a lack of understanding of the processes by which landscape change on such a grand scale as inundation by the sea could take place and to the feeling that underwater archaeology is a specialised field, best left to those who wish to dangle their toes in the water. Both reasonings are, of course, true, but archaeology is already a specialised, highly professional discipline, in which we pool our expertise and interests to construct a rounded understanding of the past. We don't ignore new fields of evidence just because we don't understand them, we try to inform ourselves and then we get someone else to supply the necessary expertise.

This book is designed to highlight the possibilities that a more rounded view of the ancient landscapes of the world, one that includes submerged lands, can bring. The intention is to dispel the scepticism with which many archaeologists still view the idea that our ancestors walked the submerged hills and valleys of Doggerland and Beringia (two of the best known submerged landscapes). It aims to clarify the issues behind the rise in global sea-level that has been related to the ending of the last Ice Age, and to shed light on the new technologies that allow us to explore these ancient worlds. It won't make you into an underwater archaeologist, but it will inform you about the potential of the lands beneath the sea. If you wish to join in, you will require further training, but at least you will be starting with enthusiasm.

The importance of the submerged landscape

At the Last Glacial Maximum, 26,000–19,000 years ago (Clark *et al*. 2009; Lambeck *et al*. 2014), lower relative sea-levels meant that large parts of the continental shelf around the earth were exposed as dry land. Other sea-level low stands have been recorded for earlier periods in the Pleistocene. Bailey has written eloquently of the archaeological implications of this, not least of the possibilities that increased landmasses offer in terms of the facilitation of the early dispersal of human communities around the globe (Bailey 2011). Sea crossings were reduced (as between Indonesia and Australia/New Guinea), or eliminated (as with Beringia which occupied the land between Russia and North America), transport was facilitated with the use of sea craft across these narrower straits, and the advantages of coastal resources helped to stabilise local communities.

Moving forward in time to the emergence of the modern world in the period right at the end of, and immediately after, the last Glaciation (from roughly 15,000 to 10,000 years ago), the exposure of the continental shelf as dry land around northern Europe and North America was similarly significant (Bailey *et al*. 2017a). In many places, such as around the coasts of Norway and the northern UK, these coastal lands were initially inaccessible due to ice over both land and sea; not that this necessarily prevented human activity, but it certainly diminished the ensuing archaeological record. In other places they remained ice free, such as the landscape of Beringia between Asia and North America. This landscape has remained hidden to modern archaeology until recently, but it is likely to have provided an important resource for those who lived at the time. The archaeology of Late Glacial groups such as the Hamburgian provides clear evidence for the advantages, and subsequent exploitation, of the plains territory to the south of the European Ice Sheets. Elsewhere, research in Sweden has highlighted the way in which the conditions created by the release of glacial meltwater into the seas at the end of the last Ice Age, together with the ameliorating climate, led to rich coastal and island environments that were taken advantage of by groups like the Hensbacka (Schmitt 2018; Persson *et al*. 2018).

The significance of the submerged landscapes of the continental shelf is thus chronologically threefold. It extends back into the Pleistocene and our understanding of the dispersal and lifestyles of early modern humans. It adds geographical variety to the potential sources of information relating to the locations and lifestyles of both the Late and Terminal Upper Palaeolithic populations of northern Europe, as well as the early populations of North America. It is directly relevant to the landscape available during the emergence of the Holocene populations of Northwest Europe. This volume will focus on the latter, without in any way intending to diminish the importance of the former.

Recognition of the submerged landscape

Observations and publications relating to the existence of submerged terrestrial materials and associated links to the possibility that sea-levels might have been lower go back at least to the early 19th century (Watt 1820). Yet, despite this respectable ancestry, almost as long as that of archaeology itself, study of the submerged landscape has been slow to receive mainstream acceptance. Even today it tends to be regarded as a specialist option within the overall profession of archaeology. There are, nevertheless, increasing numbers of projects around the world that either focus on submerged archaeology, or incorporate it into their remit. At this point in time, however, despite the publication of project results, submerged sites and landscapes have still, by and large, to penetrate museums and other popular presentations of archaeology. This is, no doubt, due partly to the exigencies of updating any museum display and the time lag between recognition in the professional sector and recognition in the world of popular archaeology. But, until consideration of the changed geographical nature of the world is regarded as essential for the presentation of any Late Glacial or Early Post-Glacial display, we cannot really assume that submerged archaeology has taken its rightful place within the world of the past.

This enhanced picture of the world does require new knowledge and new understandings. The mechanisms behind the changes in the amount of water in the earth's oceans combine with the driving forces relating to the movement of the earth's crust to create an intricate pattern of rising and falling sea-levels in relation to the land, and these patterns differ around the world. The exposure of coastal lands, and subsequently their inundation, occurs at different rates and at different times in different places. Data is lacking in many places, so that our understanding of past sea-level change often relies on sophisticated modelling undertaken on the basis of information related to glacial melting and the rebound of the land, combined with those data spots that do exist. Generalised models, such as these, provide excellent base-line studies to give an overall idea of the extent of past sea-level change, but they can never provide the accurate level of detail necessary to understand the nature of past landscapes, or the impact of the related landscape change on a specific community in a particular location. For that, it is necessary to initiate local fieldwork and analysis with the aim of constructing relative sea-level curves and topographical modelling at the site scale to reflect the specific changes that any single population will have experienced.

At the same time, the ephemeral nature and difficulties of locating many underwater sites mean that the potential of the resource is much greater than the actuality. For this reason, it is necessary to be aware of the submerged landscape, even where it is likely to be buried below modern sediments. The seabed itself may not appear to hold much archaeological potential, but across every continental shelf pockets of ancient land surface are buried and preserved. The technology is now available to study this buried landscape, even where it is not immediately visible (Figure 1.2). In many places, this provides the best way in which to begin to appreciate the true nature of locations such as Doggerland or Berengia, and even to speculate on the likely siting of the archaeological sites. Equally important, is the integration of information relating to the intertidal zone. As the area that binds the archaeological record above water with that below water, it can provide crucial material that spans apparent gaps in technique and understanding. As sea-level is prone to change, the position of the intertidal zone is, clearly, transient. Archaeologically, its value is two-fold: it can provide a modern analogy for the processes that have taken place in the past as sites and landscapes are subject to the power of the sea; and it can contain preserved terrestrial material that is, thus, easier to access. Given that any attempt to understand archaeological landscapes requires understanding of both submerged and terrestrial records, study of the evidence either side of the intertidal zone is sometimes referred to as ‘transition zone archaeology’ (Bates *et al*. 2009), the outcome of which is occasionally known popularly as ‘seamless archaeology’.

The sweeping nature of landscape archaeology poses its own problems in relation to the submerged cultural heritage resource. Curiously, these relate not so much to the investigation of the resource as to its management. In the modern world increasing demands are made on the seabed and the nature of these demands, which often relate to the extraction of raw materials, or to transport infrastructure, can cover wide areas. Management, with the aim of protecting the wellbeing and archaeological potential of the ancient landscape, needs to promote a delicate compromise between the requirements of the developers and the requirements of archaeology. For this to succeed, it is necessary that information relating to the submerged landscape is available to all and regarded as worthwhile. It is important that stakeholders and developers be involved in each stage of the process, and the passage of information between groups be regarded as essential. Recognition of the value of the submerged landscape is not just a matter for archaeologists alone, it is something to be promoted among the wider community.

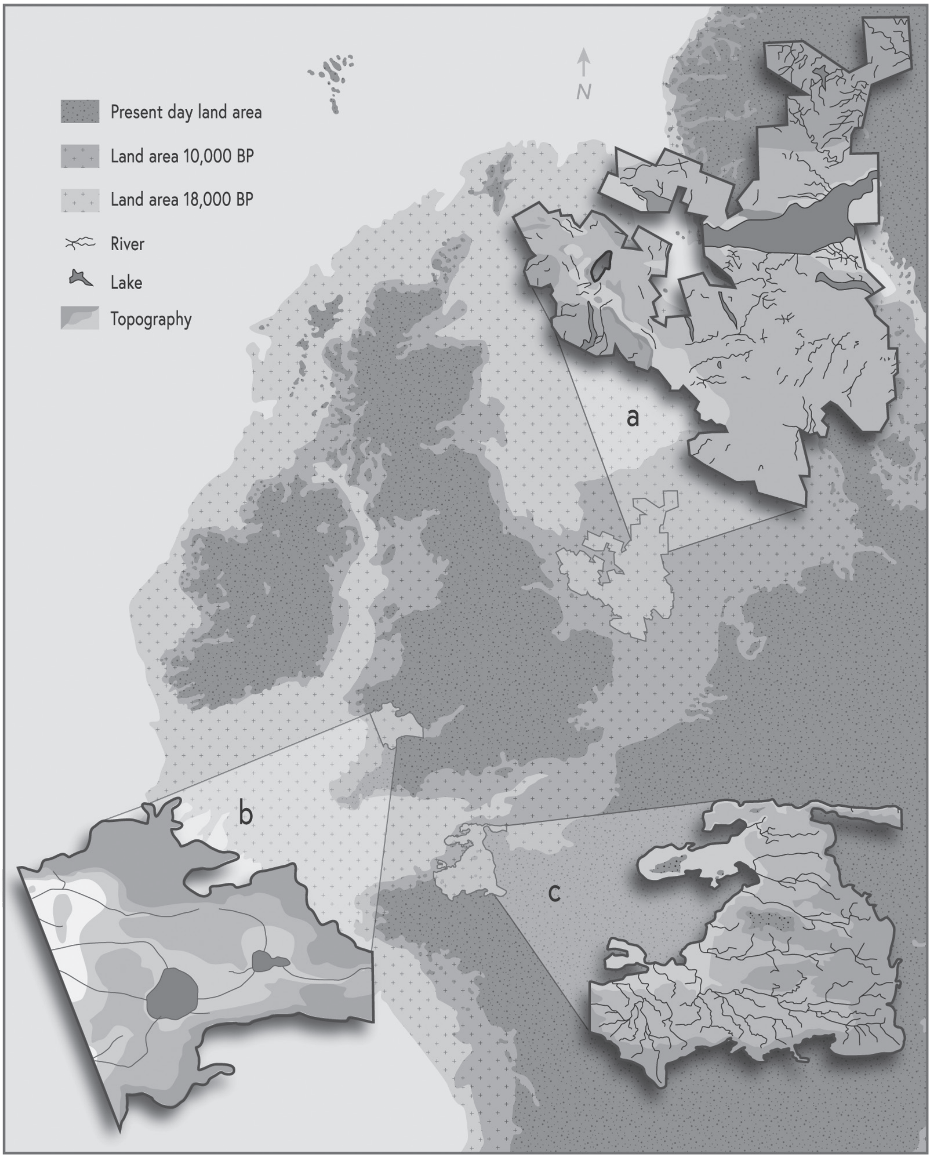


Fig. 1.2 Various research projects have taken place around the North Sea and they reveal the topography of Doggerland in surprising detail, including the locations of rivers and lakes. The three presented in the boxes here illustrate clearly the potential for reconstructing the landscape that has been lost beneath the waves: a) the principal topography and geography of Doggerland in a research area (as yet undated) off the coast of the Humber estuary, as reconstructed in Gaffney et al. (2009); b) the principal topography and geography of the Bristol Channel as it looked around 15,000 years ago (redrawn from Fitch and Gaffney 2011); c) reconstruction of the submerged landscape around the Channel Islands around 11,000 years ago, as revealed by Conneller et al. (2016). Image: Rhona Jenkins

The aim and structure of this book

The aim of this book is to provide an appreciation of the submerged landscape and its contribution to our understanding of the early settlement of the British Isles and elsewhere around the world, as well as imparting something of the specialised techniques by which this information is gained. In addition, consideration will be given to the fragilities of submerged sites and landscapes and the management practices and legislation by which it can be conserved. The volume contends that, while not all archaeologists need to practise submerged archaeology, it is as vital a part of the education of any archaeological student as studying the Neolithic or learning about wetlands. It sets out to explain the mechanisms behind the rising and falling relative sea-levels of northwest Europe, to illustrate the different times and places where submerged landscapes occur are the world, to discuss how we locate and study these ancient landscapes and how best to manage and care for them. The first half of the volume presents a primer relating to the relevant geographical mechanics and archaeological techniques (Fig. 1.3). The second half covers the investigation of submerged landscapes around the world. While reasonable cover has been attempted, this is not exhaustive, not least because the way in which the initiation of new research will very quickly make the book go out of date. There is also no attempt to describe individual projects in a uniform fashion. The study of submerged landscapes and their archaeology is a broad discipline, and, in this way, it is possible to reflect that global diversity.

While the book is aimed at those who may be embarking on a qualification in archaeology, it is also designed to be of interest to those who do not wish to study formally. You do not need to be an archaeologist to be interested in the past. The world of earlier populations pertains to us all, it was trodden by our collective ancestors. It is important that we all have a say in how it is managed and the sites and evidence that

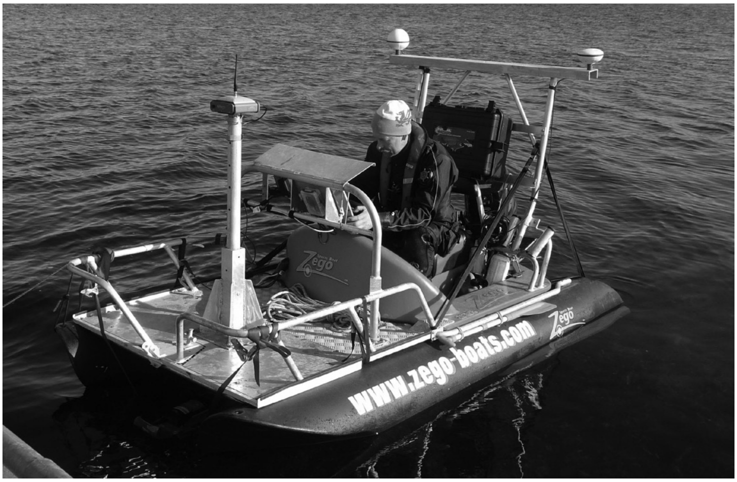


Fig. 1.3 Preparing to undertake survey work in Orkney. The study of submerged landscapes is fun

we preserve for our descendants. We cannot do this unless we understand something of the nature of the debate.

Notes

In general, this volume concerns itself only with submerged marine landscapes. There are, of course, plenty of examples of fascinating underwater freshwater archaeology around the world, including the crannogs of Scotland, the Lake Villages of Switzerland, and numerous recently flooded reservoir landscapes. To include all of these sites would have rendered the volume unwieldy. Consideration has been made of this material where it serves to illustrate a point, but sadly, those who wish to study freshwater archaeology will have to turn elsewhere.

Those who wish to get to know the topic in detail may wish to visit the SplashCOS viewer, an interactive map which records known find spots of submerged archaeological sites around Europe, http://splashcos.maris2.nl/. It is possible to interrogate the find spots and retrieve information such as date and publication (if any).

For prehistoric sites, dates are given in calibrated years before present (BP).

2. Past studies of changes in relative sea-level and submerged landscapes around the UK

The history of our understanding of the submerged landscapes of the UK is intimately tied up with the history of the study of Doggerland; the landscape that lies between Britain and the Continent of Europe. The emerging picture of Doggerland provides a good example of the way in which the dawning realisation that the shape of the land could have been dramatically different has grown and of the way in which increasing technological developments allowing the study of the submerged landscape have coincided with the intellectual realisation that there was once a land 'out there' and that we might need to know about it.

19th century work and earlier

In 1820 William Watt who lived at Skaill House in Orkney (later to become famous when he discovered Skara Brae) published a record of a small stand of fallen coniferous trees, the remains of which he discovered below the sand in the bay in front of his house (Watt 1820). He noted two remarkable things about his find: firstly, that trees such as this did not exist in Orkney at the time and had not, perhaps, existed for centuries; secondly that the find normally lay about three feet below a sandy seabed which was usually covered by fifteen feet of water (Fig. 2.1). Watt realised that his find suggested that the landscape had changed.

Watt was not the first person to understand that landscape is not immutable. As far back as the 12th century the chronicler Gerald of Wales commented on the discovery of tree trunks 'which had been covered for many ages' (Giraldus Cambrensis 1191), but academic study of the subject did not take off until the late 19th century. In 1893 Walter Traill Dennison read a paper on 'The Encroachments of the Sea' to the Orkney Natural History Society. He recorded finds of trees that had been observed below the sand at spring tide from the Bay of Otterswick in the island of Sanday (Fig. 2.2). Traill Dennison found these a melancholy sight: 'the open grave of what had at one time been an umbrageous forest, blooming in all the sylvan beauty of stately trunk, spreading bough, and green leaves; where beasts roamed and fair birds sang' (Traill Dennison 1995, 172–3). He can perhaps be allowed his poetic turn of mind given the fact that trees, never mind forests, were a rarity in his island home. Traill Dennison was in no doubt that these trees provided an indication that sea-level was once much lower and he related this to the instability of the earth's crust. He went on to cite local stories that supported his contention that the sea was slowly encroaching on the land and concluded by saying: '… our island home is doomed'. (Traill Dennison 1995, 186). His use of local stories provides an interesting example of the application of oral history in archaeology.

The wider implications of the changing sea-level were understood by John Evans in his comprehensive study of ancient Britain, published shortly after this (Evans 1897). He moved beyond coastal studies to discuss the relatively recent status of Britain as an island, noting that it must have been connected to the European Continent at least into the late Quaternary (Evans 1897, 707). This idea, of an ancient landmass that

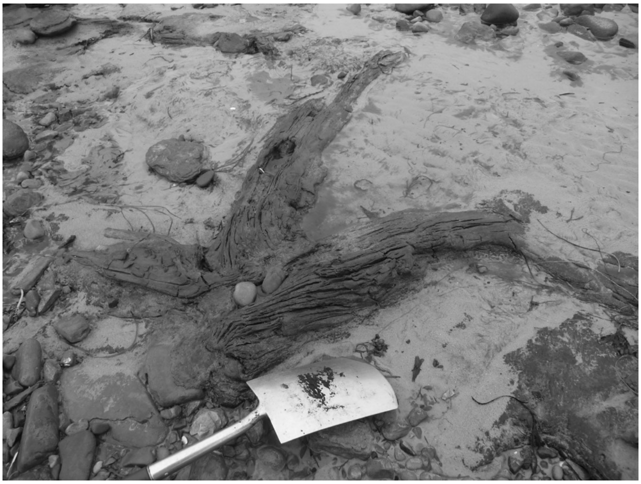


Fig. 2.1 No trace survives of the tree stumps at the Bay of Skaill, recorded by Watt in 1820, but at the Sands of Wright, some 30 km away, substantial trunks may be seen in the intertidal zone

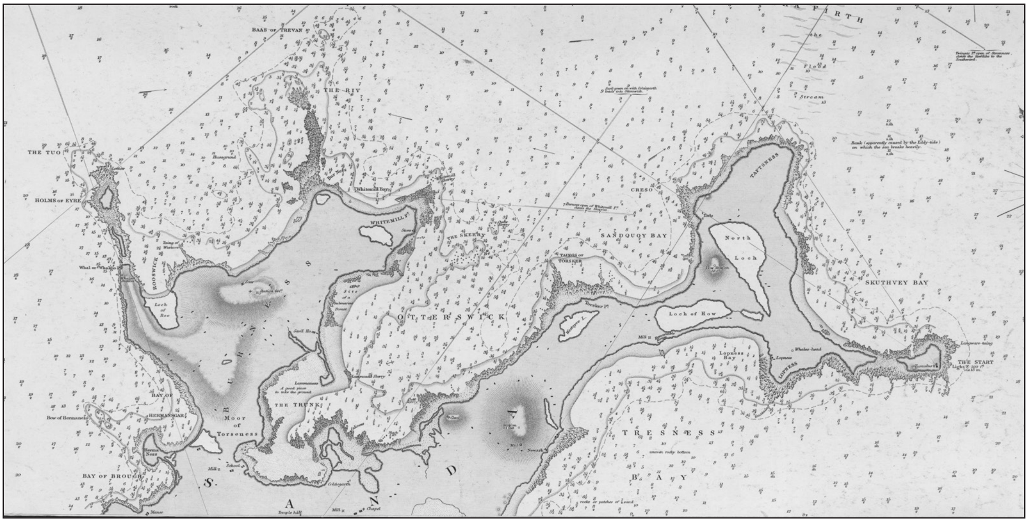

FIRTH
BAAS OF TREVAN
THE RIV
THE TUO
HOLMS OF EYRE
Stream
WHITEMILL
THE SKERRY
CRESO
SANDQUOY BAY
TAFTSNESS
North Loch
SKUTHVEY BAY
Loch of Rew
OTTERSWICK
THE START
HERMANSGAR
BAY OF
Moor of Torsoness
THE TRUNK
TRESNESS
BAY
BAY OF BROUGH
S A N D

Fig. 2.2 The site of the submarine forest at Otterswick, Sanday, Orkney, was recorded on the Hydrographic Office chart of the North Ronaldsay Firth, surveyed by Commander Becher and Lieutenant Thomas in 1848. Reproduced by permission of the National Library of Scotland

incorporated the British Isles, was picked up by Lubbock in 1913 though he cited evidence from underwater river beds that sometimes extended far out to sea, rather than the occurrences of submerged trees around the coast. Lubbock's work is remarkable for placing Britain on a landscape that extended along the continental shelf and far to the west of Ireland (Lubbock 1913, 415, fig. 255).

Clement Reid

In the same year that Lubbock published his revised work, the study of this unknown landscape really took off with Clement Reid's publication dedicated to the subject (Reid 1913). As his title, *Submerged Forests*, indicates, he focussed on the findings of tree remains below the present sea-level in order to investigate the previous changes to the geography of Britain. Reid was the first to catalogue finds from around the coasts of England and Wales (often, but not always, recovered during excavation to expand docklands) and he acknowledged the role of changes in sea-level in the former geography of our shores: 'Nothing but a change of sea-level will account …' (Reid 1913, 5).

Reid was a geologist and had worked with the Geological Survey of Great Britain for forty years. His book coincided with his retirement and provides an admirable summary of a lifetime's study (Grant and Sturt 2017). In addition to citing the different occurrences of submerged trees around our coasts, he leads the reader through consideration of the stratigraphy of different finds and looks at various explanations. Reid was able to see the wider picture and brought a variety of evidence to bear, resulting in the inclusion of the first attempt to map the ancient geography of the landscape between Britain and the Continent in detail (Fig. 2.3). Reid's map incorporates an approximate coastline and shows the existence of large rivers. His text discusses the likely flora and fauna of the area and laments the fact that few of the human remains and artefacts to be found in submerged deposits had been preserved (an interesting side line on the existence of those elements at all). We forget the ease with which radiocarbon and other methods of dating allow us to calculate relative age until we reread works such as this wherein Reid devoted several pages to calculating possible deposition rates in order to work out the time during which recent sea-level has apparently been unchanged and thus get back to the period when the changes took place. Presciently, he ascertained that the submerged forests were likely to have been extant during the Stone Age. Reid postulated that sea-level rise

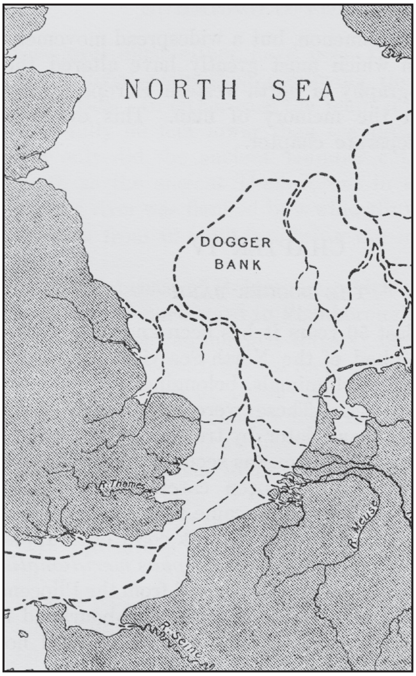


Fig. 2.3 Clement Reid's map of the North Sea showing a lowered coastline, the position of the Dogger Bank and the hypothetical courses of major rivers. From Reid (1913)

started around 3000 BC and ended around 1600 BC. As we shall see he was out on both counts, though not by much given the methods he had at his disposal. Perhaps his most surprising, and relevant, conclusion was that these changes had taken place in relatively recent times in terms of the antiquity of the earth. Clement Reid opened our eyes to the possibility of transformation in the recent geographical, and archaeological, history of the British Isles.

Reid was aware of the important role that the Dogger Bank played in this ancient landmass. He did not coin a name for the area, but he did suggest that Dogger Bank may have continued as an island long after the rest of the area had disappeared. He suggested that future research might focus on the bank as a potential source of human remains and stratified deposits. He was the first to recognise that the submerged lands did not comprise merely a featureless bridge between Britain and the Continent, though it would be several decades before research techniques had advanced enough for investigation of the topography to take place.

Clement Reid's volume quickly became an established aspect of academic wisdom. In 1915 Keith devoted a whole chapter of his synthesis on '*The Antiquity of Man*', to 'The People of the Submerged Forest'. Keith drew on existing work to relate the elevation and depression of the land to periods of glaciation and drew on research by people like Evans (1911) to discuss recent theories that the earth's crust was flexible and that the weight of ice upon a particular area might depress that area. His hypothesis was speculative, and it would be a long time before advanced modelling made it possible to mimic the processes he described, but he believed that the weight of the great ice sheets and the flexibility of the earth's crust were tied up with the existence, and subsequent loss, of the area we have come to know as Doggerland (Keith 1915).

The recognition of Doggerland

By the mid-1930s Graham Clark was able to develop Clement Reid's work, adding information from the developing field of palaeoenvironmental analysis together with the recent find of a harpoon, the Colinda Harpoon (Pl. 1), found off the Norfolk coast (Clark 1936). Clark envisaged a single Mesolithic culture, the Maglemose, which occupied land from southern Scandinavia to England. He appreciated that the bed of the North Sea had been part of that landmass, with its own vegetation, rivers and topography. Curiously, though Clark maintained his view that Britain was part of a great northern landmass (Clark and Piggott 1970, 131), others tended to consider the area more as a bridge that had connected Britain to the Continent of Europe, rather than an area worthy of settlement in its own right (Jacobi 1976; Morrison 1980; Smith 1992).

In the late 1990s the situation changed with the publication of a seminal work by Bryony Coles (Coles 1998). She was the first to name the lost terrain 'Doggerland', in honour of Reid's pioneering studies. She provided an overview of the effects of deglaciation on both the earth's crust and past sea-levels, and she produced some of the first illustrations for archaeologists of the changes in the shape of Doggerland that had taken place since the Last Glacial Maximum. Coles concluded with a consideration of the inhabitants of Doggerland. As soon as the paper was published it all seemed so obvious: it was the paper that I wished I had thought of myself, and I am sure I was not alone in that feeling! Coles speaks of Doggerland as a true landscape, one with hills and rivers and with its own vegetation and fauna, changing from arctic tundra at the glacial maximum, to woodland and forest in the Holocene. She drew on finds from the waters as well as existing knowledge of the human communities to both east and west in order to speculate on the changing settlement patterns of the area, even suggesting a possible distinction between the groups who may have inhabited the interior and those of the coast in the Holocene. She also considered, briefly, the impact of the gradual loss of this great landmass on those who lived there, though without any of the catastrophic turn of mind that has characterised more recent studies (see below).

The North Sea flint

Coles introduced her paper with consideration of the discovery of a small, flaked flint tool from the northern North Sea, roughly half-way between Shetland and Norway (Long *et al.* 1988). She noted that it is not as romantic as the find of the Colinda Harpoon in Clark's day. In many ways, however, the find of the North Sea Flint, as it has come to be called, was just as important because it was this that alerted modern archaeologists to the fact that the North Sea held archaeological potential on a scale that was previously unimagined. It was a find that touched me personally because I had been called in by colleagues at the British Geological Survey to identify it when it first came up.

The Flint was recovered in 1984 from the upper section of a seabed core taken during the prospection for oil (Fig. 2.4). At first, we assumed that it must relate to some loss at sea, whether during a prehistoric sea crossing or the more recent journey of a collector. But within a few months I was called back to discuss the fact that the location from which the flint had been retrieved would have been a deltaic area at the edge of dry land during the Last Glacial Maximum. This opened the possibility that the artefact had actually been in situ. It is, of course, not possible, or wise, to populate the whole of a continent on the basis of one tiny flint, but it is fair to say that the flint opened people's eyes to the potential of the North Sea as a place that might once have been inhabited.

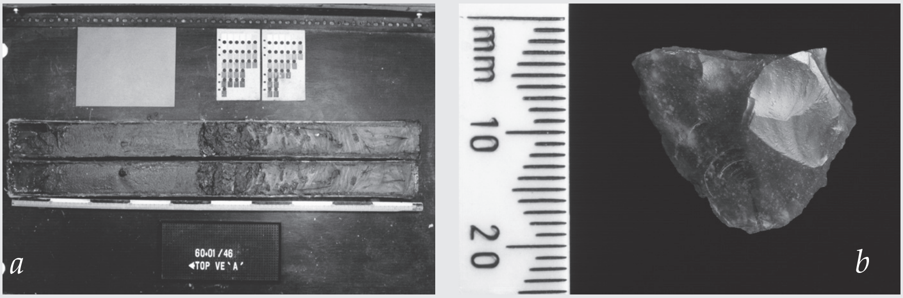


Fig. 2.4 a) The original core with the North Sea Flint in position at the centre of the sand layer to the left of the core; b) close-up of the flint

Coles' paper pulled together information relating to the artefacts that had been found in the area of the North Sea. Most came from the southern half of the North Sea and, though research work in Denmark and Norway has recovered relevant information further north, finds of artefacts in British waters in more recent decades have still focussed on the southern area. While the North Sea Flint highlighted the potential of the northern part of Doggerland, therefore, this is a potential that has remained as yet unfulfilled.

One reason for this lies in the conditions in the north. Deeper, more active waters make research difficult. Nevertheless, Coles' paper coincided with developments in research technology which have opened up a whole new world to those who wish to know more about the seabed and the ancient landscape that it might conceal. For this reason, the paper marked a turning point in the study of the submerged landscapes of the British Isles. Not only were archaeologists alerted to the possibility that Britain might once have been part of a much bigger landmass, for the first time they had the means to go out and investigate specific areas of that landmass.

New technologies

The technology in question came about not from a desire to know more about the past but rather from the need to understand the sea and the seabed. There were several factors driving this. Perhaps most obvious was the burgeoning oil industry. While it was necessary to identify new oil reserves, it was also necessary to exploit them safely and bring the oil safely and efficiently ashore. Techniques of prospection were important, alongside techniques to scan and inspect the seabed and the equipment that was sited there. Other techniques were developed to facilitate different aspects of the exploitation of the sea: cable laying; shipping; gravel extraction, the late 20th century saw the use of increasingly sophisticated methods to understand the environment within which people were working and archaeology was quick to take advantage of this.

One of the first to embrace the new technology, and those who were practising it, wholeheartedly was Vince Gaffney, then at the University of Birmingham, now a professor at the University of Bradford. Gaffney remains one of the leading practitioners in research on the submerged landscapes of Britain and further afield. He has written engagingly of how eccentric his original request for data was seen by the oil services company he first approached but he obtained the material he needed and has gone on to make good use of it. Gaffney's well-illustrated volumes, published with colleagues in 2007 and 2009, developed the concept of Doggerland and introduced it to the public and to an academic audience (Gaffney *et al.* 2007; 2009). His work continues.

Gaffney's work will be discussed in more detail later on (Chapter 12). In brief, he has made good use of seismic survey data (see below) obtained by the energy industry from the upper sediments below the seabed. Although this data was not of interest to those who had collected it, because they were looking into the possibility of oil in much deeper strata, Gaffney realised that the information it provided on buried land surfaces immediately below the seabed held the key to reconstructing the topography of parts of Doggerland at different slices of time in the past. The detail that Gaffney was able to recover surprised many archaeologists and played an important role in awakening interest in the submerged landscape and the ways in which it had changed.

Gaffney's research team continues to investigate the use of new technology to provide more detail of the ancient landscape no matter how inaccessible it may seem. Their recent work makes use of ancient DNA (aDNA, see below p. 70) recovered from sediment cores taken at key locations in the seabed in order to provide information relating to the plants and animals that once lived there. They are also exploring techniques of modelling drawn from the gaming industry that can help to visualise Doggerland and facilitate consideration of the behaviour of the communities who made it their home.

Studying the causes of relative sea-level rise

At the same time that Gaffney was working on the modelling of physical land surfaces using data drawn from seismic survey, advances in data collection and other modelling techniques allowed the development of research into other aspects of Doggerland and submerged land surfaces around the world. The rise and fall of relative sea-level that is responsible for the emergence and subsequent inundation of the land depends upon two factors: the flexibility of the earth's crust and the amount of water in the oceans. During and after the Last Glacial Maximum, the ice sheets that covered much of the northern hemisphere affected both of these factors. Seawater was caught up into the ice itself, thus reducing the amount of water in the oceans; this process is known as eustasy. Meanwhile, the weight of ice that had settled on the earth's crust caused that crust to be depressed, a process known as glacio-isostasy. As deglaciation took place, so a series of eustatic and glacio-isostatic adjustments (reductions in water levels set against rises in the land surface), led to changes in the relative height of sea-level against the land. These processes are described in more detail below (Chapter 3).

Academics have yet to collect enough data to provide detailed information on these changes around Britain, so they rely on modelling the overall picture using data collected from a number of key points. Developments in computer programming, together with more accurate information relating to the details of deglaciation have allowed the production of increasingly precise models to illustrate the changing palaeogeography of the British Isles over the last 15,000 years. Many teams have been working on this in recent years, and not just in the UK. It is research that is relevant to other disciplines and not just archaeology. With regard to archaeology, in 2013 Fraser Sturt and his colleagues (Sturt *et al.* 2013) combined palaeogeographic analysis with archaeological information in order to provide a series of models to illustrate likely changes in the geography of the British Isles at a series of 500-year intervals from 11,000 years ago to the present day. Work such as this allows archaeologists to visualise the land within which the communities in whom they are interested were living. It also allows them to think about the changes to that landscape as sea-levels changed and how these transformations may have impacted on those prehistoric communities.

Broadscale modelling, of the type undertaken by Sturt and his colleagues, is important in order to move our understanding of Doggerland forward, but it

Models versus maps

It is important to remember that a model is not a precise rendering of accurate data. It is not a map. Essentially a geographical map is built from detailed data sets that provide accurate information relating to the state of the land (e.g. height, vegetation, water courses) at any given point. A map provides a precise depiction of an area of land. A model, however, assumes that it is not possible to provide that amount of accurate data. It makes use of specialised programming in order to fill in the gaps between data sets. Where data sets are relatively close, a model can be detailed, we call this high resolution. Where the gaps between the data sets are greater, so the resolution of a model will drop. Resolution will also depend on the amount of change you can expect between the different data sets. In some circumstances, little change might increase the resolution even where data spots are drawn from widely spaced locations. In other places, even locations that are relatively close may have experienced widely differing transformation so that the accuracy of the 'guesses' drawn up to fill the space between individual data points is reduced. Though they may look similar it is important not to confuse models and maps. A map is a precise rendering of information. A model is a best guess and often embraces a considerable scale so that detailed information regarding specific locations is lacking.

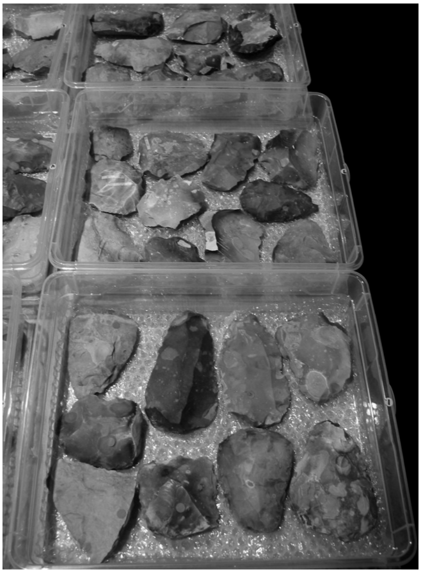


Fig. 2.5 Some of the stone tools recovered from Area 240 at the time of the original find. © Wessex Archaeology

remains theoretical until we have more finds from archaeological remains. This too has been addressed in recent decades. In the southern waters of the North Sea, research and education work has been able to draw on an imaginative programme set up to provide finance drawn from the taxation of the commercial extraction of aggregates. The Aggregates Levy Fund was introduced in 2002 and ran until 2011 with the specific aim of undertaking investigation and monitoring of the marine environmental and archaeological resource. Through the use of the fund, research on the ancient landscapes was combined with awareness programmes for those working commercially in the North Sea and this has resulted in the recovery of archaeological material such as animal bones, Neanderthal skulls and, in other places, handaxes (Fig. 2.5) and other stone tools (Tizzard *et al.* 2014). Every find enhances our understanding of the prehistoric world and, in addition to those engaged in aggregate extraction, a variety of industries including fishing, energy, and infrastructure are now accustomed to recognising and reporting material. Finds such as these have long been recognised in adjoining waters such as the Dutch sectors of the North Sea (Roebroeks 2014), and, though it has now ended, the use of the Aggregates Levy Fund has been highly significant in facilitating the development of submerged landscape studies in the UK.

Future prospects

The investigation and management of the submerged landscapes that surround the UK in the early decades of the 21st century is healthy, though it still focuses mainly on the southern sector. One hundred years since the publication by Clement Reid of his work on *Submerged Forests* there are teams involved in the investigation of different aspects of the ancient landscape including archaeological remains, topographic change, and vegetation history all round Britain (Bicket and Tizzard 2015). Work takes place at a variety of scales (Fig. 2.6) from modelling across wide geographical areas (e.g. Sturt *et al.* 2013), to coring and survey within a single sea loch (Bates *et al.* 2013a; 2016). Given the increased powers of archaeological inspection it is now possible for all to play a part in unpicking the nature of the hidden landscapes around the UK whether they are collecting data from sediment cores or sitting behind the latest computer.

Around the North Sea, the study of submerged landscapes has benefitted from developments in individual countries, together with academic networking, to produce a sophisticated suite of models, together with some detailed information (Bailey *et al*. 2017b; Flemming *et al*. 2017b; and see the collected papers in the *Netherlands Journal of Geosciences*, 2014, vol. 93, such as Peeters and Cohen 2014). Elsewhere around the globe the study of submerged landscapes has tended to take off in more recent decades, prompted largely by the developments in available technology together with discoveries around the North Sea (Evans *et al*. 2014). The vagaries of changing relative sea-levels have long been researched in Baltic countries, where they are essential to understanding

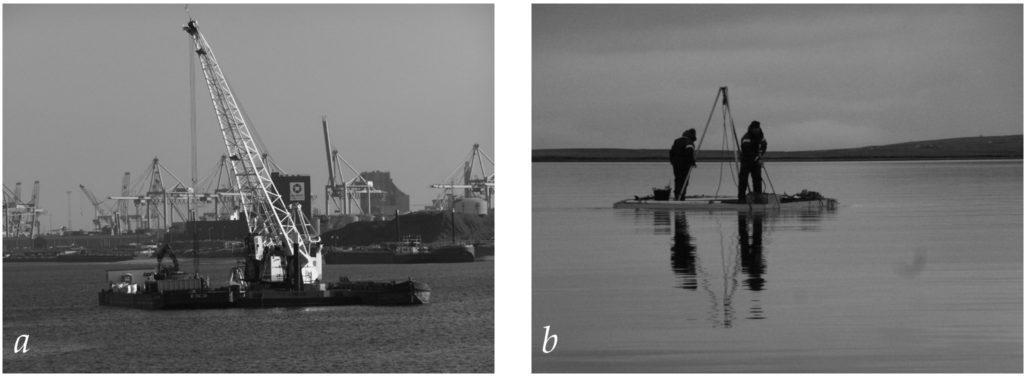


Fig. 2.6 Work takes place at a variety of scales: a) the Triton at work during the extension to Rotterdam Harbour. From this research platform it was possible to sample material from the seabed 20 m below and examine it for archaeological finds. Image courtesy B. I. Smit, Cultural Heritage Agency of The Netherlands; b) coring in the Bay of Firth, Orkney. This research platform allows examination of the seabed at depths of 2–9 m. Image: Richard Bates, University of St Andrews

human activity down the millennia, though the restrictions of available technology prior to the second half of the 20th century limited work in that period to the study of sea-level high stands.

In 1983 Masters and Flemming published their edited volume on *Quaternary Coastlines and Marine Archaeology* (Masters and Flemming 1983). This was a ground-breaking work that introduced the concept of past seal-level change and submerged archaeological landscapes. It tackled research around Europe and the Americas, as well as in Australia. The papers are rarely referenced today, but they are worth reading for the glimpse they provide of a discipline in the making. This was one of the first volumes to identify the international value of submerged landscapes as significant locations for the study of early global migrations. The study of submerged landscapes may have been in its infancy at this time, but there was clearly enough research to get people thinking.

Study of the submerged landscape has a respectable ancestry going back well over a century. There are sites, and landscapes, around the world, new techniques of study are still being refined, the data base is penetrating further and further back in time, and knowledge is increasing exponentially (Flemming 1998). Despite that, there is still a tendency for traditional land-based archaeologists to regard it as a specialised field, which does not touch upon their work. As this volume demonstrates, the value of research related to the submerged landscape is integral to all archaeological studies. Not only is it necessary for a full understanding of the context of any archaeological project, it also provides the key to our understanding of many of the earliest migrations around the globe at a time when lower relative sea-levels facilitated movement between the continents that we know today.

3. The mechanics of rising relative sea-levels and changing coastlines

Relative sea-level change

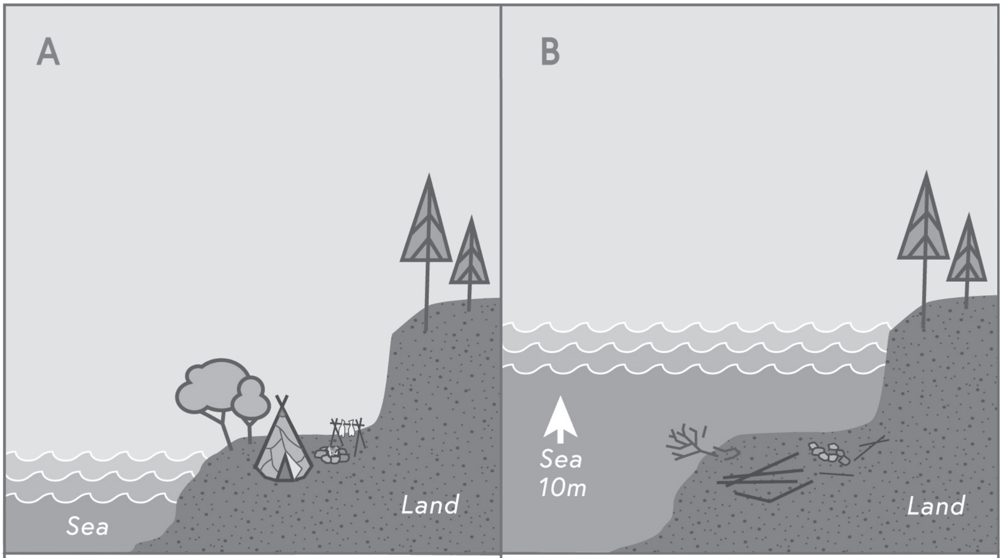
In order to understand submerged landscapes around the world, it is necessary to understand why sea-levels rise and fall. This is the result of the complex interplay of two factors: changes in the amount of water in the ocean result in fluctuations in sea-level (eustatic change); and changes in the height of the earth's crust result in the rise and fall of the land (isostatic change). The changes in the height of the sea that were experienced by our ancestors are not the result of variation in water level alone, but rather of variation in the land as well. For this reason, it is common to talk of *relative sea-level* change when discussing the emergence (or disappearance) of coastal lands. The amount of dry land at any one time depends on the relative height of the sea as set against the height of the land (Fig. 3.1). It is therefore possible for falling absolute sea-levels to result in the inundation of coastal landscapes if the landmass is falling faster than the sea. In this case, relative sea-level will still be rising despite the reduction in levels of ocean water. It is a complex process.

This chapter will discuss the processes that lead to changes in relative sea-level and will give brief examples of different submerged landscapes. These will be discussed in more detail in later chapters.

Glacio-eustasy: Ice melt and water levels

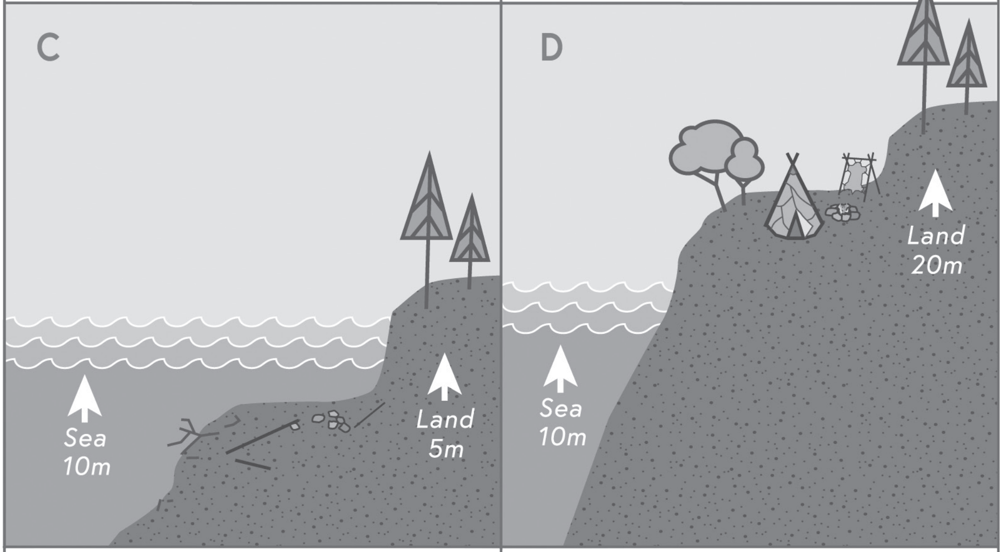
The global fluctuation of water volume in the oceans is known as eustasy. One of the main drivers of the amount of water in the ocean is the amount of water taken up by ice sheets and glaciers around the world. In general, during a colder period, when ice sheets cover much of the earth's surface, more water is locked into the ice so that sea-levels fall. As the ice cover melts, then water is released back into the oceans so that absolute sea-levels rise. This is known as glacio-eustatic sea-level change.

Research indicates that at the height of the last glaciation, some 20,000 years ago, global sea-levels were about 125 metres lower than today. These measurements are taken from areas such as Barbados and Tahiti, known as far-field sites, well away from the centre of ice cover so that there has been little change in the level of the land (see p. 23).


A
Sea
Land
B
Sea
10m
Land

Sea & land

The sea-level rises by 10m
= an absolute rise in sea-level of 10m


C
Sea
10m
Land
5m
D
Sea
10m
Land
20m

The sea-level rises by 10m and land rises by 5m
= a relative sea-level rise of 5m

The sea-level rises by 10m and land rises by 20m
= a relative sea-level fall of 10m

Fig. 3.1 Relative movement in sea-level takes place as a result of the balance between movement in the earth's crust and the rise and fall of the sea. Image: Rhona Jenkins

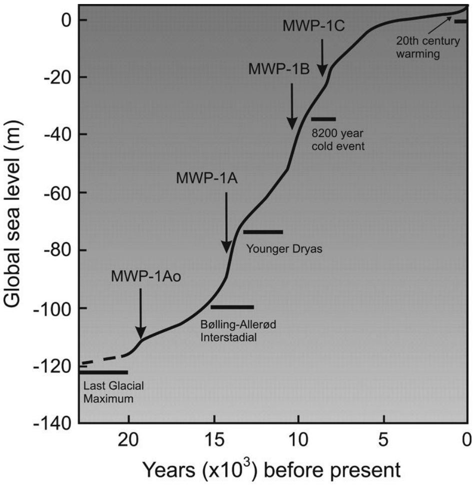


Fig. 3.2 Generalised sea-level curve since the last ice age showing the rapid rise during recognised meltwater pulses (MWP). Image: NASA/Vivien Gornitz (public domain), via Wikimedia Commons

Using measurements based on coral growth and other sea-level indicators (see p. 37), it has been possible to work out a very generalised absolute figure for relative sea-level that could be applied globally (Dawson 1992). Since then absolute sea-levels have been rising because of the general release of ice from the retreat and thinning of the last great ice sheets.

The rise in sea-level is not a uniform process through time, however. The chronological records of change, known as sea-level curves (see p. 38), indicate periods of slower rise, interspersed with episodes of more rapid rise (Fig. 3.2). Occasionally, these stages of more rapid rise appear as dramatic increases on the sea-level curve; in the millennia since the Last Glacial Maximum there are four of these and they are known as Meltwater Pulses. As the name suggests they are related to the increased release of water from the ice sheets. Meltwater Pulse 1A occurred between 14,700 BP and 13,500 BP and the precise source of the waters is still controversial, some argue that it is related to the release of water from Antarctica (Bassett *et al.* 2005; Deschamps *et al.* 2012), while others favour the Laurentide Ice Sheet over North America (Tarasov and Peltier 2006; Bentley *et al.* 2010; Gregoire *et al.* 2012).

Though it is possible to see the evidence relating to the Meltwater Pulses in the Greenland ice core record (Liu and Milliman 2004), there is, to date, no unequivocal evidence for them on land. From the archaeological point of view, therefore, the rising seas in these periods had little impact on local communities who would have had plenty of time to adapt technology and economies to the changing physical conditions. It is worth noting, however, that they also influenced climate, so that they are not without impact in human terms (Stanford *et al.* 2006).

It is an interesting comment on the approaches of different scholars, that, while a rise in relative sea-level of 10 m over 500 years is a lot to a geographer, it is less significant to an archaeologist who is considering the individual experience. Communities experiencing that scale of change may well have been aware that, from generation to generation, the coastline underwent alteration. Over time the shape of the land would change, but this is not necessarily catastrophic. Year by year, those seeking to return to a favoured settlement site would experience tides that gradually crept higher and higher. It is not disastrous, however, given the level of awareness and skill recognised within a coastal hunter-gatherer community, people would have time to adapt their living sites to the new conditions (Wickham-Jones 2014; forthcoming).

Lake Agassiz and Lake Ojibway

At the height of the last glaciation much of northern North America was covered by the Laurentide Ice Sheet. As the ice melted, a series of huge meltwater lakes developed along its southwest margins. The best-known of these is Lake Agassiz which covered much of Manitoba, Ontario and Saskatchewan, and to its east lay Lake Ojibway, which was comparable in size. The drainage of these waters towards the end of the life of the Laurentide Ice Sheet was indeed catastrophic and may have been the biggest flood the world has ever seen. Estimates of the impact of this on global sea-levels vary from a rise of around 0.4 m to 2.2 m (Dawson 1992; Teller *et al.* 2002; Li *et al.* 2012), though it would not have been a uniform figure due, among other things, to the gravitational pull over local sea-levels. Measurements suggest that this drainage took place around 8400 BP over a relatively short space of time. There is, to date, no evidence regarding its impact on coasts in Scotland; local communities would have experienced a series of higher than normal tides, but, given that this was a period when the tide would have been slowly rising anyway, it is likely to have been just one part of the ever-changing world which was the norm for those who lived here in the Early Holocene.

Other types of eustasy

The amount of water in the ocean is not only affected by global ice cover, other types of eustasy occur.

Tectono-eustasy refers to the way in which movement in the plates of the earth's crust impacts on the size of the oceans. The Atlantic, for example, is slowly widening due to the separation of the plates on either side of the mid-Atlantic ridge. In other areas colliding plates reduce the size of the ocean such as to the west of Chile and Peru where the Nazca Plate is moving eastwards towards and under the South American Plate.

Geoidal-eustasy refers to the way in which the level of the ocean is affected by gravity in order to produce an uneven surface. This is partly impacted by the size and density of local landmasses and partly by alterations in the gravity field of the earth. One factor impacting on local gravity is the gravitational pull between ocean water and ice sheets. For this reason, local deformation was greater at times such as the Last Glacial Maximum. Understanding of geoidal-eustasy is still in its infancy.

Glacio-isostatic adjustment: the flexibility of the land surface

Although the earth's crust provides a stable surface for human activities, in reality it is highly flexible due to the fact that the lithosphere (crust), which is relatively rigid, floats upon a weak, pliable, body known as the mantle or asthenosphere. This in turn surrounds the core, which is divided into a solid inner core and a liquid outer core.

The weight of an ice sheet upon the outer crust therefore results in deformation of the earth's mantle beneath it. Where the ice is thickest downwards deformation will be greatest, to either side of this, beyond the ice margin, the landmass tends to rise to form a forebulge (Fig. 3.3). When the ice melts, as the weight is lifted, the land will slowly return to its original position.

The impact of this crustal deformation on the patterns of coastal and relative sea-level change is complex. Simplistically, where the land is deformed upwards (at the edge of the ice) relative sea-level is likely to fall, while it will rise where the land is deformed downwards (towards the centre of the ice), but, in reality, the situation is, of course, more intricate than that. The ice sheets of the last great ice age were not uniformly thick so that the amount of crustal deformation depends upon the thickness of overlying ice. Ice cover across Europe varied greatly so that our understanding of the relative height of sea-level in any place at any time is dependent on information relating to the thickness of ice at that place. This process is known as differential glacio-isostasy. Given that no one was around to collect accurate data on ice thickness at the time, the estimation of ice cover is another job for the modellers who combine a variety of geomorphological and other data to produce likely reconstructions of the ice sheets at any one place (see the work of the Britice project https://www.sheffield.ac.uk/geography/staff/clark_chris/britice_v2/about). In order to reconstruct the history of changing relative sea-level over time since they melted, we need to understand the sequence of ice melt around Europe and elsewhere.

Earthquake instability

In places, tectonic instability can also result in submerged land surfaces. This has been particularly the case in the eastern Mediterranean where whole cities such as the Bronze Age site of Pavlopetri, now submerged off the coast of southern Greece, are currently the subject of research (Henderson *et al.* 2011). On occasion this may be the result of a specific earthquake (as with Port Royal, Jamaica, see below), but more commonly it is the result of long term instability which has resulted in the vertical displacement of land over a period of many centuries. Activity of this type has been studied around Cyprus (Galili *et al.* 2016) and in the Aegean (Sakellariou and Galanidou 2016). One of the most famous examples is represented by the Roman remains in the Gulf of Pozzuoli, in Italy (Aiello *et al.* 2012; D'Argenio *et al.* 2004). The columns of a marketplace at the centre of the great harbour city here display evidence of marine erosion, from a period when the crust was lower, and thus underwater (even in historic times). Ground level here is

A mobile crust

While we are all accustomed to the idea that the surface of the earth is formed of plates that have moved across the face of the globe, it is more disconcerting to realise that the crust is also subject to vertical displacement. One of the best ways to visualise this is to think of sitting on an inflatable air mattress on the beach. When you sit in the middle the mattress will sink to accommodate you, while the two ends will rise to either side of you. This is a crude, but effective, illustration of the impact of an ice sheet upon the land surface below it.

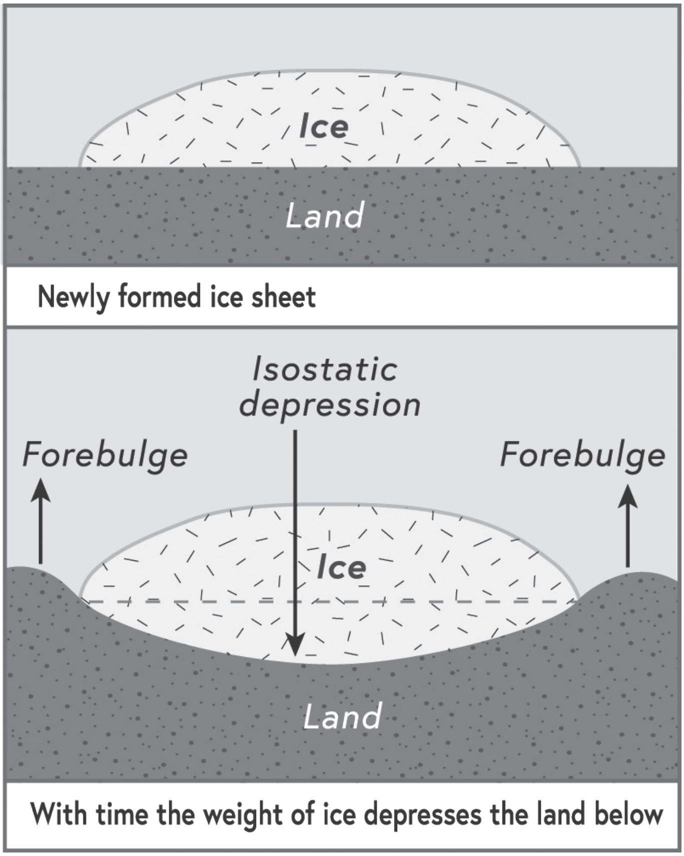

Ice
Land
Newly formed ice sheet
Isostatic depression
Forebulge
Forebulge
Ice
Land
With time the weight of ice depresses the land below

Fig. 3.3 The flexibility of the earth's crust means that the weight of an overlying ice sheet will deform it. Image: Rhona Jenkins

subject to considerable vertical displacement due to the filling (and emptying) of a great magma chamber below the Campi Flegrei (the Phlegrean Fields), the name given by the Romans to the area of volcanic activity around the city which lies to the west of Naples.

Ancient coastlines

The coastline today comprises a series of features with which we are all familiar. Cliffs; caves; sea-stacks; beaches; estuaries and rocky platforms: all of these make up the background to any trip to the coast (though not necessarily all together). They reflect the different conditions of the coast today as geology, water conditions, and former weather all interact to produce different geomorphological landforms. These elements were also characteristic features of former coastlines, and, where sea-levels have changed, the earlier features may survive, abandoned well away from the present coast, as indicators of previous shores. These features have been recorded both above present water levels and submerged, below the present sea; they provide important sources of information

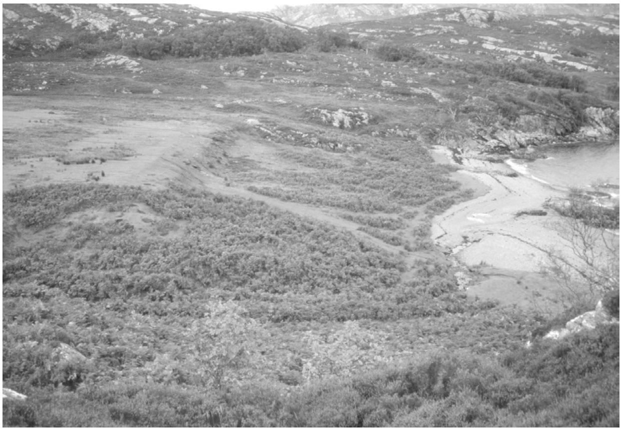


Fig. 3.4 Camas an Leim, Applecross, Scotland: the raised beach. The platform of the raised beach to the left lies in close proximity to, but above, the present shore. Image: Scotland's First Settlers

relating to past coastal conditions (Flemming 2017b).

Where relative sea-level has been higher than the present day the traces of old shorelines may be etched into the landscape. These comprise a number of well-known coastal features (Kelsey 2015). One of the most common is the raised beach, which often comprises a ridge (or ridges) of old beach material now lying well above the height of the sea (Fig. 3.4). Raised beaches may be formed of shingle, rock or sand; they may retain a stony surface, but some have now grassed over. It is sometimes possible to make out a previous cliff line behind this, perhaps with old sea caves or even rock stacks (Pl. 2). Occasionally, dune systems also lie stranded well above the present sea-level. As the coast can both rise and fall, even in a relatively short time, it is not uncommon to record older raised beaches and cliff lines which have, in their time, been re-shaped by more recent incursions of the sea (Fig. 3.5). One of the best examples of this in Scotland lies on the island of Jura (see below) where the sea has undergone a number of rises and falls.

Case studies

UK: Scotland

Argyll, Oban and the West Coast

In Scotland, the ice was thickest to the east of the town of Oban on the west coast. To the north and west of Oban the ice grew thinner and the edge of the ice margin lay offshore from the present coast. By 15,000 years ago deglaciation had freed the islands and much of mainland Scotland from any ice cover, leaving a substantial ice cap over the central and western highlands (Clark *et al.* 2009). Current research is refining our understanding of the different thicknesses of ice cover across the British Isles and the processes of deglaciation, so we still have much to learn about the individual ancient shoreline features that may be seen today.

The weight of the ice cover means that downwards crustal deformation was greatest around Oban, while glacio-isostatic movement around Orkney, Shetland and the Western Isles towards the periphery of the former ice sheet (where the ice was thinner) was considerably less (Dawson *et al.* 2017). As deglaciation commenced, the lower surface of the crust here meant that relative sea-level towards the heart of the ice cover was considerably higher than today (resulting in raised beaches), while towards the edge of the ice it was lower than today. Since deglaciation, relative sea-level in these

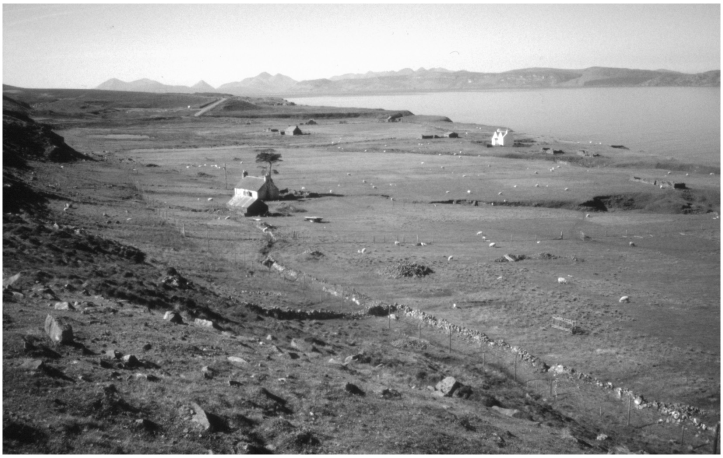


Fig. 3.5 Lonbain, Applecross, Scotland: the relict coastal features here date from a period of higher relative sea-level during the Late Glacial or earlier. A clear cliff line behind the coastal platform may be seen to the left of the photograph. Image: Scotland's First Settlers

outer areas has been steadily (but not uniformly) rising, while in other locations such as the mainland coast of Argyll it fell at first, as the land bounced back upwards, before rising to above present sea-level, as relative sea-levels rose when water was released into the oceans. Finally, relative sea-levels here fell again to the present-day height, leaving behind a sequence of raised beaches at difference heights.

The island of Jura – raised beaches

In the Late Glacial period, relative sea-levels around the west coast of Scotland were initially higher due to the isostatic impact of considerable crustal deformation from the weight of ice on the land. One of the best examples of a raised beach that dates to the higher shorelines of the Late Glacial period lies on the island of Jura. To the north of Loch Tarbert on the west coast of Jura a sequence of shingle ridges represents old beach lines isolated as the relative sea-level fell in the early millennia after deglaciation. Above them a low cliff indicates the highest level reached by the sea and may pre-date the last glaciation; below this another, more prominent, cliff marks the inland edge of a lower beach platform on which further shingle ridges may be seen. This lower cliff was formed during the Younger Dryas (known in Scotland as the Loch Lomond Stadial), a brief period after the onset of deglaciation during which colder conditions returned (around 12,900–11,500 years ago). The shingle ridges here mark the position of falling relative sea-level in more recent millennia. Research indicates that by 6500 years ago relative sea-level here had risen again to about 12 m OD, cutting into and masking earlier shorelines. Since then relative sea-level around the island has been steadily falling.

Orkney – a drowned post-glacial landscape in the north of Scotland

Orkney lay to the edge of the Scottish ice sheet so that it experienced less crustal deformation. Relative sea-level at the end of the last Ice Age is estimated to have been

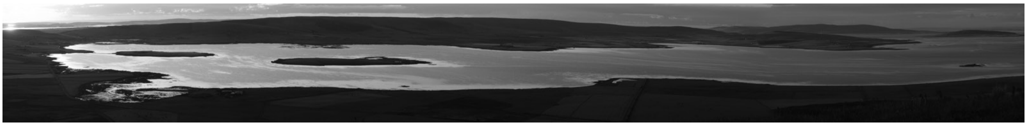


Fig. 3.6 The Bay of Firth, Orkney, Scotland is a good example of a drowned landscape where the tops of ancient hills project above the present surface of the sea

as much as thirty metres lower than the sea-level of today. Since then it has been steadily rising. Research in Orkney indicates that the first millennia of deglaciation saw a rapid rise as relative sea-levels reached a height of around –6 m OD by *c.* 8500 cal BP, though this rise would not have been uniform. Periods of rapid rise will have been interspersed with slower periods. We have still to obtain data on the precise heights of relative sea-level at enough dates (known as Sea-Level Indicator Points) in order to illustrate the wiggles in the sea-level curve. Because relative sea-level since the end of the last Ice Age has always been lower than that of today, Orkney does not have raised beaches that relate to the post-glacial period. Any features relating to earlier Holocene coasts in Orkney lie below the present water level (Fig. 3.6): submerged cliff-lines, caves and blow holes have been recorded by detailed bathymetry, for example in locations below the cliffs of the West Mainland of Orkney. Raised beaches do exist on the island of Hoy, but these all relate to a time towards the end of the Late Glacial period, when relative sea-level was much higher.

UK: England and Wales

Around England and Wales relative sea-level changes both chronologically and geographically. Generally lower relative sea-levels in earlier periods mean that the potential for submerged Palaeolithic sites and landscapes exists around most of England, however, with regard to more recent periods, the local impacts of glacio-isostasy mean that the land is rebounding at different rates in different places. Wide scale studies include the work of the West Coast Palaeolandscapes Project in the Bristol Channel and Irish Sea (Fitch and Gaffney 2011). Higher resolution, targeted studies of submerged Mesolithic landscapes include work such as that in the Solent (Momber 2011) and among the intertidal forest remains at Borth (Godwin and Newton 1938, and more recent research to be published by Martin Bates, pers comm. March 2018). In some places Neolithic remains have been recognised in the subsea or intertidal zone, notably at the site known as Seahenge in Norfolk (Watson 2005).

The Isles of Scilly

Like Orkney, The Isles of Scilly have experienced a history of relative sea-level rise since the end of the last Ice Age due to their position towards the edge of the ice sheets. Data has been collected from the shallow waters between the islands to show a variable rate of past sea-level rise with the most rapid change taking place between 4500–4000 BP during the late Neolithic and Early Bronze Age (Charman *et al.* 2016). The archipelago assumed its present shape around 3500 BP in the Bronze Age, though much of the central lagoon area persisted as saltmarsh until around AD 600. The shallow waters of Scilly have preserved a rich palaeoenvironmental record including deposits of submerged peat, and areas of submerged forest. There are also examples of prehistoric features that run under water: in the intertidal zone around the islands of Samson and Bryher there are linear features that have been interpreted as field walls (Pl. 3). Other features have been interpreted as hut circles, and there are also fish traps and kelp processing remains. In many places, the submerged archaeology has been preserved beneath more recent sediments (Robinson forthcoming) promising potentially good preservation.

Europe

The history of the Baltic

The relative sea-level history of the Baltic is complex, affected by the weight of overlying ice at the Late Glacial Maximum, lowered relative sea-levels, and the blocking of the present entrance to the Baltic in the *Öresund* (Harff *et al.* 2017; Rosentau *et al.* 2017; Jöns and Harff 2014). Because of this, the waters of the Baltic have fluctuated between freshwater and brackish. During the last stages of deglaciation, the freshwater Baltic Ice Lake was alternately dammed and drained due to a sequence of erosion and uplift events. Around 11,700 BP water levels dropped and sea water entered the basin, when contact with the sea was established through the lowlands of southern Sweden. At this point, it is known as the Yoldia Sea. As the land rose due to isostatic uplift, so the outlet to the sea was blocked around 11,000 BP and water levels rose once again to become a huge freshwater lake: the Ancylus Lake. Sea water reached the lake once again around 9800 BP and by 8500 BP it had transformed into a brackish sea, known as the Littorina Sea. At this point, the present access through the Kattegat was established. In southern Scandinavia, relative sea-level reached present heights around 6000 BP.

Nevertheless, the Baltic situation is also impacted by differences in crustal uplift between the north and the south. The coasts of the Baltic preserve a sequence of raised beaches that reflect this past relative sea-level change. Because of the work that has been done to unpick the transformations in the area and work out the relative chronology of the succession of fossilised coastal features, it is not uncommon to date archaeological material in the Baltic by the beach formation on which it sits; this is a useful device when organic dateable material is absent or when excavation has not taken place (Schmitt 2013). The assumption is that communities chose to settle within easy reach of the sea, and habitual campsites would move nearer to the coast as relative sea-levels dropped.

Morbihan, Brittany

The Gulf of Morbihan, off the south coast of Britanny, is a slowly submerging landscape, due to a combination of eustatic and isostatic change since the low relative sea-levels of the Last Glacial Maximum at which point it comprised dry land, crossed by two main river systems flowing east to the sea (Daire *et al.* 2014). As relative sea-levels have risen so the river systems that crossed the area during the lowstand became estuaries (between 10,000 and 7000 BP) and the landscape gradually disappeared to leave behind the islands and peninsulas of today. The varied topography of this landscape means that inundation led to the deposition of sediment and the formation of coastal bars as well as to submergence. On land, this is a rich archaeological landscape and it is likely that a considerable amount of evidence has been submerged. Surviving evidence for Mesolithic activity here indicates the presence of coastal hunter-gatherers in several locations; remains include burials (now on islands) such as Teviec and Hoedic (Ghesquière and Marchand 2010) and settlements (Beg er Vil; Marchand and Dupont 2012). By the Neolithic, the landscape had broken into islands, some of which had monuments built upon them (Pl. 4); leading to submerged sites such as Er Lannic (Gouezin and Le Gall 1992) and Kerbougnec (Cassen *et al.* 2011). Exploratory survey work has demonstrated the potential of remote sensing for the recovery of archaeological information here (see Fig. 11.1; Cassen *et al.* 2010; 2011).

The Aegean

The Aegean combines a history of eustatic sea-level change with geotectonic processes such as earthquakes and landslides to produce a varying pattern of land and sea interaction throughout recent millennia. The location of the eastern Mediterranean across various tectonic plates has made this area an active one due to the convergence of the African Plate and the Eurasian Plate; Sakellariou and Galanidou sum the situation up: 'Owing to the continuously evolving landscape, the geography of an area during a high- or low-sea-level stage has never persisted into the next, equivalent sea-level stage.' (2016, 7). In general, there is considerable potential for submerged landscapes in the Aegean, summarised by Sakellariou and colleagues (Sakellariou *et al.* 2017), who put it into the context of existing knowledge relating to Palaeolithic and Mesolithic remains and environmental resources, but considerable work needs to be done to realise it. The Aegean comprises a landscape of shifting geography, important to both Pleistocene and Holocene populations (Sakellariou and Galanidou 2016) and it is important to understand this geography at any particular slice in time in order to understand fully the lifestyles of the communities who made it their home.

The global picture

Beringia

Beringia occupies the area between northeast Asia and Alaska, together with a large landmass along the northern shores of these states. Lower global sea-levels during the glacial maximum at the end of the Quaternary revealed this area which was considerably more than a 'land bridge', though that is how it is often considered by research today. Beringia was possibly available to human communities in the area as early as 40,000 years ago until about 11,000 years ago and research here is highly significant because Beringia is thought to have played a key role in the migration of people from Asia into the Americas.

Given its northern latitude, Beringia was susceptible to global climatic trends meaning that, though it may have been populated as early as 30,000 years ago, it seems to have been uninhabited during the glacial downturn from 25,000 years ago until around 15,000 years ago by which time conditions had improved.

Archaeological evidence for the actual process of colonization and inhabitation of Beringia is lacking, submerged deep beneath the difficult waters of the Bering Straits and the north Pacific. Interpretation of its importance is therefore based on genetic evidence, together with analysis of artefact styles, palaeoenvironmental conditions, and dated sites on the land either side. Previous theories regarding the existence of an ice-free corridor through the ice sheets on the North American mainland that would have blocked the way south for the early communities until around 12,000 years ago have now been discarded in favour of migration into North America, possibly at a much earlier date, around 16,000 BP, along the resource rich coastal zone of Beringia (Erlandson *et al.* 2007). Beringia is discussed in more detail below.

Sundaland

Sundaland lies in more tropical climes, stretching southwards from the mainland of southeast Asia across the South China Sea to Borneo and the Philippines. It, too, owes its existence to lower sea-levels around the globe at the end of the Quaternary. It differs from many other submerged landscapes, however, in that it did not facilitate the dispersal of early hominins between continents in quite the same way. Despite the way in which Sundaland appears to stretch out towards Australia there was always a considerable stretch of sea between the two. Conditions here would have made this a difficult passage to cross, though recent research suggests that the first crossings took place as much as 50,000 years ago and would have involved an open sea crossing of between 3 and 5 days by at least 50 individuals (Bird *et al.* 2016). Genetic research complements this picture and indicates that human groups spread rapidly around the continent of Australia once they arrived (Tobler *et al.* 2017).

Sundaland comprised a tropical environment of rainforest and mangrove swamp rather than the high latitude environment of many submerged landscapes. Inundation of the area was underway by 17,000 years ago and has been linked by some to the rise in relative sea-level associated with Meltwater Pulse 1a (see p. 21; Pelejero *et al.* 1999). By 10,000 years ago it had advanced sufficiently to be linked to developments in the monsoon. Sites on the surviving landmasses in the area indicate that it was inhabited by hunter-gatherer groups who used stone tools and exploited the available resources, possibly developing agriculture around 10,000 years ago. Genetic studies reveal a considerable amount of population movement, both between landmasses and further afield, which may be related to the processes of inundation (Soares *et al.* 2008; Lijn *et al.* 2009).

The Caribbean: The Port Royal earthquake

Occasionally, a submerged landscape can be formed from a single event. One of the best documented is the earthquake that resulted in the destruction of Port Royal, Jamaica, on the 7 June 1692. Port Royal was a thriving city with a population of around 7000, it was a significant trading centre and fortified naval base with a reputation for wealth and decadence. In the late morning of 7 June it was struck by three earthquake shocks, followed by a tsunami. Records indicate that over two-thirds of the town disappeared as the land sank, including the harbour wharfs and warehouses, the church, shops and a considerable amount of housing. Port Royal did recover and went on to play an important role as a British naval station until 1905, but it never re-achieved its former glories, and today the population numbers around 2000. Because of the rapidity of destruction, and lack of subsequent development in that precise area, much of Port Royal is well preserved underwater. Behind the harbour it seems that the land dropped vertically so that there has been little displacement of remains. Excavations by Texas University have revealed some intimate detail of the surviving structures including a cobbler's shop, a kitchen and accommodation for servants and slaves as well as unusually complete information relating to construction both inside and outside the houses (Hamilton 1984; 1988). Time capsules such as this are rare, but fascinating.

4. Reconstructing relative sea-level rise

Points of analysis

While the presence of coastal geomorphological features above or below the present shore is a clear indicator of coastal change and can be recorded to provide information relating to the sequences of past relative sea-level change (Kelsey 2015), it is also necessary to provide a chronology for the transformation. This requires compilation of a number of dated data points that can be combined into a relative sea-level curve.

The precise reconstruction of changes in past relative sea-level relies on the accurate collection and dating of evidence relating to the height of the sea against that of the land at specific times. It is a process with many different interlocking elements, the varied techniques of which are comprehensively described with reference to sites around the world by Shennan and colleagues (Shennan *et al.* 2015). Though few archaeologists collect their own sea-level data, it is important to have a general understanding of the methods involved because accurate sea-level information is central to our interpretations of the submerged landscapes of the past.

A variety of data sets can be collected in order to provide information on past relative sea-level and this is combined into a series of data points, known as Sea-Level Index Points (SLIPs). The precise development, or diminution, of brackish conditions as evidenced by microfauna in sediment deposits at specific sites can be used to indicate the onset, or reduction, of marine influence in an area and these can often be dated. In some parts of the world the occurrence of coral reefs may be used to provide a date for the height of the sea at different times. Where it is not possible to date a sea-level rise absolutely, it is sometimes possible to provide relative dates for the changes. Outcrops of coastal rock, such as beachrock and aeolianite, can sometimes be dated absolutely but, if not, they help to build relative chronologies. Once calculated, the combination of a number of SLIPs can be used to provide information on relative sea-level change across both space and time.

Sea-Level Index Points (SLIPs).

SLIPs comprise the specific locations at which information relating to the height of the sea at a specific date in the past can be collected (Shennan *et al.* 1983). For a Sea-Level

Index Point to be valid it is necessary to collect enough data to constrain the information. Rashid highlights five principal attributes of SLIPs (Rashid 2014):

- location;
- age;
- altitude;
- indicative meaning;
- reference tide level.

Clearly it is important to record the precise location of the spot – this is done using a D-GPS or other locational system, such as a total station. Reliable absolute dating is crucial, although one date is useful, where a topographically intricate coastline is concerned, it is better to have enough dates to make sure that you fully understand the landscape changes through time as relative sea-level rise may vary, and even fluctuate. The present altitude of the sample is necessary in order to work out the change that has occurred since the sea was at the height recorded in the sample. For example, if the sample occurs at a height of a metre above mean sea-level today then relative sea-level has fallen a metre since the sample was formed. The indicative meaning relates to an understanding of the way in which the sample was formed, does it relate to material that would be deposited at the high tide mark for example, or to erosion by a mean tide? It is also essential to have an assessment of the tidal range, or reference tide level, in the relevant time period. This may be determined by the identification of sensitive microfossils (see below). Tidal ranges vary considerably around the world and by season: in the Bay of Fundy, eastern Canada, they can be over 16 m; in Rio Grande, Argentina, up to 12 m; while in Bergen, Norway, they are around 1.5 m.

Essentially, the SLIP is a record of the date at which rising relative sea-levels inundated this particular location, or when falling relative sea-levels dropped below it. In order that it be useful in building up the greater picture with other points, a number of limiting factors need to be considered such as topography, geomorphological change, and the nature of the substrate – whether the site is based on hard or soft deposits and thus whether or not it has been vulnerable to erosion. Given the importance of good stratigraphic control, for example in establishing SLIPs and dating the individual events that make up the stratigraphy, it is perhaps surprising that few authors discuss in detail the processes of transgression at a scale commensurate with the resolution of the records used to track sea level rise. Bioturbation, for example, is likely to affect any soft inter-tidal or seabed surface, though few projects specifically investigate it (but see Sharma *et al.* 1987; Horton *et al.* 2007; and van Hengstum *et al.* 2011, for examples of research into the impact of bioturbation on sea-level controls). Lambeck provides a useful list of sources of information on sea-level height from his work around the Italian coast (Lambeck *et al.* 2004), including:

- Microfauna such as marine fossils like bivalves and gastropods;
- Speleothems (stalactites and stalagmites) with marine overgrowth;
- Sediments with biological and microfossil markers such as diatoms;

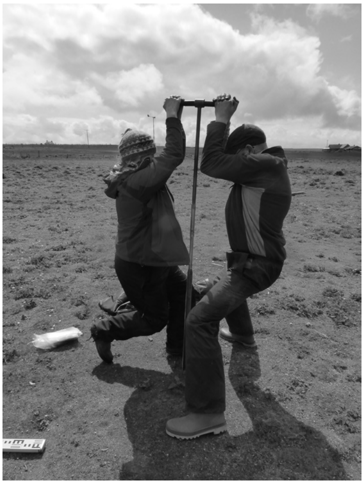


Fig. 4.1 Using a gouge auger to extract a sediment core

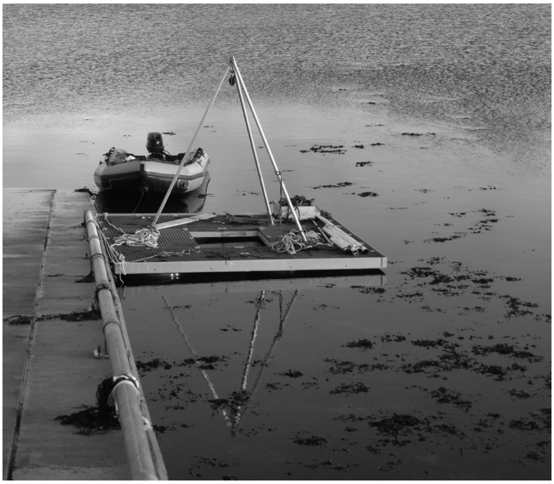


Fig. 4.2 Preparing the raft and the vibrocorer to take a core at sea

- Fossil bearing beach sands;
- Beachrock;
- Submerged archaeological sites.

Data collection from coring

Samples may be collected in many ways including the removal of sediments in cores or, from open sections, using block tins. The techniques for coring are described in detail below in Chapter Six; it is an efficient method of obtaining material for analysis, not least because, in general, the equipment is relatively portable, thus facilitating access to remote locations. Many corers operate manually (Fig. 4.1), always a plus for archaeological and palaeoenvironmental fieldwork where power sources can be expensive and hard to transport. It is also a relatively simple matter to extract the core sample, seal it, and transport it to the laboratory. Gouge augers comprise a narrower coring device with which is easier to examine the potential of a sediment before going to the effort of using a broader corer such as a Russian corer. Where the sediments are very intractable, a variety of motorised devices exist to assist in the extraction of material. It is possible to take cores both on land and underwater (Fig. 4.2), in many cases the equipment used is the same for marine coring with the obvious addition of a boat where necessary.

Once a core has been obtained it is important to seal it carefully into a rigid container for transport, such as a split drainpipe covered by tightly wrapped cling film. This ensures that the various sediments stay in place and that they are not contaminated by modern material.

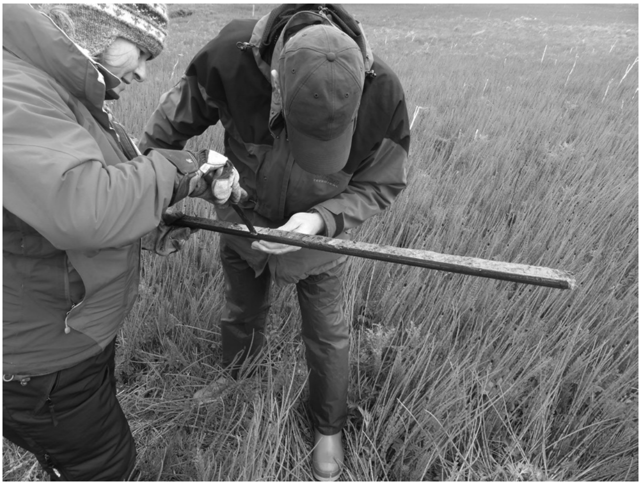


Fig. 4.3 Examining the core sediments within a gouge auger

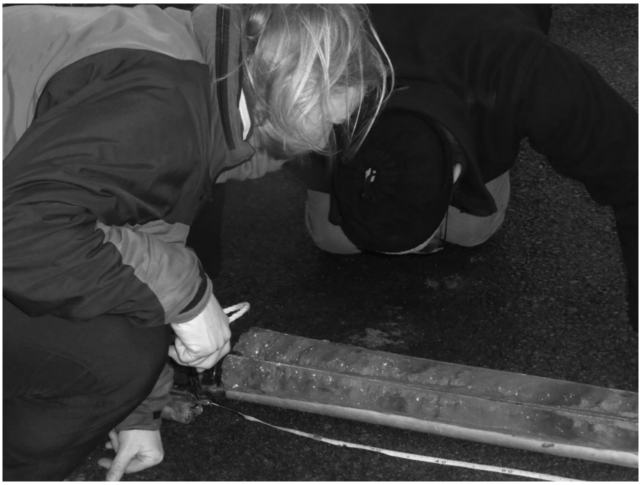


Fig. 4.4 Variations of sediment are often clearly visible in the broader sample taken by a Russian corer

Sediment analysis

The long samples of sediment obtained when a salt marsh, lagoon, lake, or other soft sediment along the shore is cored contain a wealth of detail about the conditions in which that sediment has accumulated and this is the material of relevance for the SLIP (Fig. 4.3). Conditions may have changed from freshwater to salt, or dry land to marsh, with rising relative sea-levels and vice versa as sea-level falls (Fig. 4.4). Many different elements may be preserved within the sediments, including pollen, insect remains, and other microfossils, so it is important to select the samples to analyse, and the material that will be investigated, with care (see papers in van de Plassche 1986). In general, only very small quantities of sediment are required, so that careful sampling will leave duplicate material for further research as new techniques of sediment analysis are developed. Where the microfauna or plant remains indicate evidence of a transformation from freshwater to marine conditions, or vice versa, it is possible to date that transition and use the date to build a SLIP, provided, as noted before, that there is enough data to constrain and properly understand the transformation.

Dates are often obtained through the radiocarbon assay of organic material in the sediments at the point of the change to or from marine or brackish conditions. By itself a date is of limited value to assess past sea-level change. As noted above, the altitude at which the date has been taken is crucial, as is the full understanding of the sediments that have accrued, and of their geographical context. Given the requirements of different species it is important to understand which environments they prefer and how they react to change: individual species react differently to the incursion of sea water. It is also necessary to record the sediment itself: sediments may be compacted, or truncated. Diatoms, foraminifera, shells, ostracods and pollen can all be used to provide information about a site and the incursion of the sea.

As the change from freshwater to marine conditions, or vice versa, at any one spot takes place over a period of time, it is rarely an abrupt change. Changes in sea-level usually take place relatively slowly in human terms, sometimes across many years, and they incorporate gradual alterations in salinity, and accompanying species. Furthermore, inundation is unlikely to take place at a uniform speed, so that it may be that, over a period of centuries, sea-level rises relatively quickly in the first five hundred years and then very slowly for the next five hundred years. Multiple dates, often from multiple cores, are necessary in order to record information relating to the speed of change at any single location. The combination of environmental evidence and dates is likely to reveal a gradation of change over a chronological period.

Coral reefs as indicators of past relative sea-level change

Coral reefs may be relatively easily dated, often with uranium-thorium dating which measures the relative amounts of the two elements, though various corrections are necessary, given the vagaries of sea water (Dutton 2015). As individual corals have very specific growing conditions in relation to depth, temperature and nutrients, they provide a useful and widely occurring indicator of past relative sea-level change as long as it is still possible to measure factors like height in relation to present sea-level. Hibbert and colleagues provide a useful discussion and global database of coral SLIPs to which they encourage others to contribute (Hibbert *et al.* 2016).

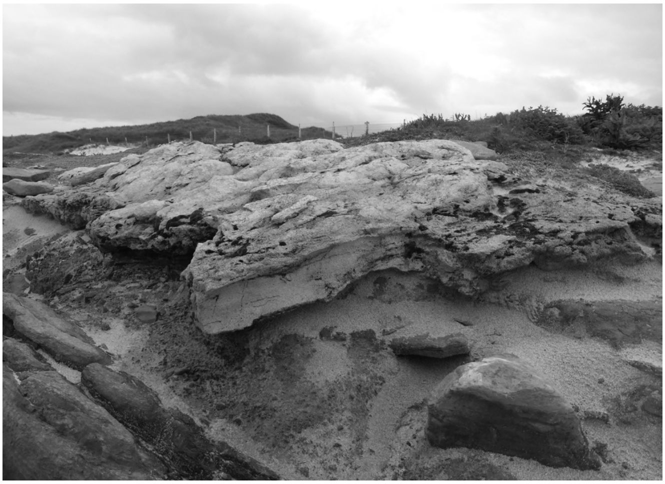


Fig. 4.5 Beachrock at Grobust, Westray, Orkney

Beachrock and aeolianite

Beachrock forms in the intertidal zone from the lithification of the beach sediments. It occurs mainly along tropical coasts, though it has also been recorded at higher latitudes (Fig. 4.5).

It can accumulate rapidly, though the precise mechanisms that trigger its formation remain open to discussion (Turner 2005). It requires a soft, rapidly accumulating sediment, seawater and groundwater, together with bacterial action which means that outcrops of beachrock are usually discontinuous along any stretch of beach. Outcrops of beachrock provide an indication of the position of the intertidal zone, and may be stranded above or below the present shoreline depending on the fall, or rise, of relative sea-level. The use of beachrock as a sea-level indicator is subject to various technical constraints related to the evolution of the coast at that particular location (Kelletat 2006), but it forms a valuable part of a suite of relevant techniques (Mauz *et al.* 2015). As it is hard to date the outcrop itself, dating is more commonly achieved when the rock has formed around an archaeological or organic element.

Aeolianite refers to the rock formed from the cementation of wind-blown sand deposits. It often occurs in the zone immediately above a beach and can also be used as an indicator of past sea-level change given the same constraints relating to the understanding of the general environment of coastal evolution as with the use of beachrock. Where precise dating is not possible, outcrops of beachrock and aeolianite can still provide useful relative indicators of the processes that have taken place along a shore, even where they are now to be found underwater (Martin and Flemming 1987).

Modelling

By combining a number of SLIPs, it is possible to model the way in which sea-levels have changed through time, known as a sea-level curve, and across a wider geographical area. Of course, one problem with this system is that, in order to get an accurate picture of relative sea-level change across a wider area, the SLIPs need to be spaced relatively closely together. Because sea-level change is affected by local topography, where points are spaced too widely apart, the inferred gradient between two points can become too generalised. Pertinent topographical features, for example those which may hold back rising seas, such as a local promontory, may be missed. Recent work in Orkney has shown just how important it is to select an appropriate distance apart for your data points (Pl. 5). The highly localised conditions along any single stretch of coast mean that the collection of closer and closer data points can become very tempting, though it is time consuming, expensive, and often fraught with difficulty. In principle, it is necessary to think carefully about the desired final interpretation before deciding on the spacing of the data points to be collected (Wickham-Jones *et al.* 2018). If you wish to examine the way in which changing relative sea-levels have impacted on individual human communities, then relatively closely set data collection points are necessary, located within a relevant territorial area. If you are interested in the changing resources of a wider area, then the data points can be spaced further apart.

Accurate data is rarely easily available across large geographical areas. So, it becomes necessary to predict the rates of sea-level rise between known places. While this is useful, it reduces the resolution, and thus the accuracy and value (Wickham-Jones *et al.* 2018). One way to overcome this is to combine the sea-level information with information from other relevant fields such as the modelling of glacio-isostatic readjustment, or the way in which

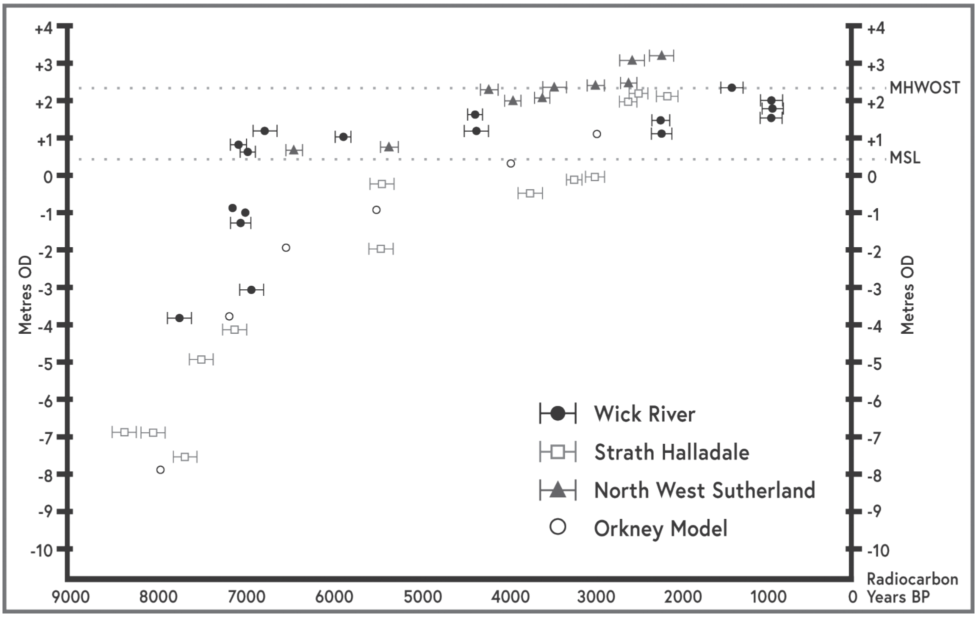


Fig. 4.6 A typical sea-level curve drawn from Sea-Level Index Points taken around the north of Scotland. Each point indicates the relative height of sea-level at a particular date. By using a number of SLIPs from related locations it is possible to improve the resolution of the model. Image: redrawn by Rhona Jenkins from Sue Dawson, University of Dundee. Data for Wick River, Strath Halladale, and northwest Sutherland taken from Dawson (1999)

the earth's crust has rebounded after the release of the downward pressure of the ice caps. Nevertheless, as this information is often based on the modelling of other elements, precise accuracy remains elusive. Because these gaps between sea-level data points are thus filled by inference rather than information, the geographical interpretations become models rather than maps. This is an important distinction because to call them maps would imply a false sense of accuracy. A model that 'joins the dots' across a wide area will blur the detail, leading to a generalised interpretation, that, while useful to generate overall ideas of the scale and rate of past relative sea-level change (e.g. Sturt *et al.* 2013), cannot be used for more targeted interpretation, such as the way in which past relative sea-level change might have impacted on specific communities. In order to consider the impact of inundation on a local community, it is necessary to generate enough sea-level index points to produce a model that can take account of very specific local topography and the way in which it has changed through time (e.g. Bates *et al.* 2013a; 2016).

Where it has been possible to collect a series of SLIPs relating to an area through time, they can also be combined to produce a sea-level curve, or indication of general rates of rise within a given chronological period (Fig. 4.6). Once again it is important to remember that, though this is based on empirical data, this is a model and that the issues relating to the spacing of the data points relate to the chronology of a sea-level model as well. Chronological resolution is dependent on the number of vertical points. All sea-level curves tend to smooth out the minute details of relative change from year to year. In reality, sea-levels do not rise (or drop) at a uniform rate across a decade or even a century, but the problems of collecting data, and the vagaries of archaeological dating, mean that they will never be illustrative at such high resolution. Any individual sea-level curve is, therefore, masking a more detailed picture of rapid change interspersed with periods of little change. While relative sea-level curves have, therefore, to be used with care, they are important tools for the archaeologist. Most curves are more appropriate for generalised time spans rather than the individual, generational experience of a single human community.

Equally important for the interpretations of the sea-level models that we create is the understanding of the geomorphological conditions, and possible topographical change, at the location in which we are interested. The past topography does not always mirror the present coastline and places that lie at a similar height may not always be inundated at the same time even within a relatively small area. For example, where a location has been protected from the rising seas by an offshore bar, then the dates within a series of SLIPs may be unexpectedly recent. Wider geomorphological survey to record and analyse the topographic features of the coast is always important and can add to the overall understanding of coastal evolution (Kelsey 2015).

Modelling is a useful tool, but caveats like these are vital for archaeologists because we deal with human experience. Local and regional changes to past relative sea-level can, for example, impact on more than just the physical shape of the coast. The human experience of tidal amplitude and currents is also, to a certain extent, dependent on local topography, with knock-on effects on the extent of the intertidal zone, harvesting of local resources and even ease of access to the sea and appropriate maritime technology. It can be difficult to make the leap from broadscale research to personalized reactions, but it is important to be aware of the need. High resolution models can provide appropriate data to look at issues such as these possible impacts on individual communities. Low resolution models are more useful for looking at the scale of landscape change across broader areas. It is important not to push the data beyond the resolution at which it has been constructed. It is also important not to confuse models with maps. Though a model may have been drawn to look like a map; while a map is an accurate representation of data, a model can only ever provide an informed indication of the likely picture between various data spots. And those data spots may be far apart. It is easy to fall into the trap of over-reliance on models.

Case studies

Scotland

Most sea-level histories of Scotland rely on modelling to give an overall picture. Due to the great thickness of ice cover over much of the country, Scotland has undergone major fluctuations in relative sea-level in the Early Holocene. Because the depth of ice varied considerably across the country, relative sea-level change in one place can also vary greatly from the sea-level history in another area (Fig. 4.7), even across a relatively short geographical distance, due to the processes of differential glacio-isostatic uplift.

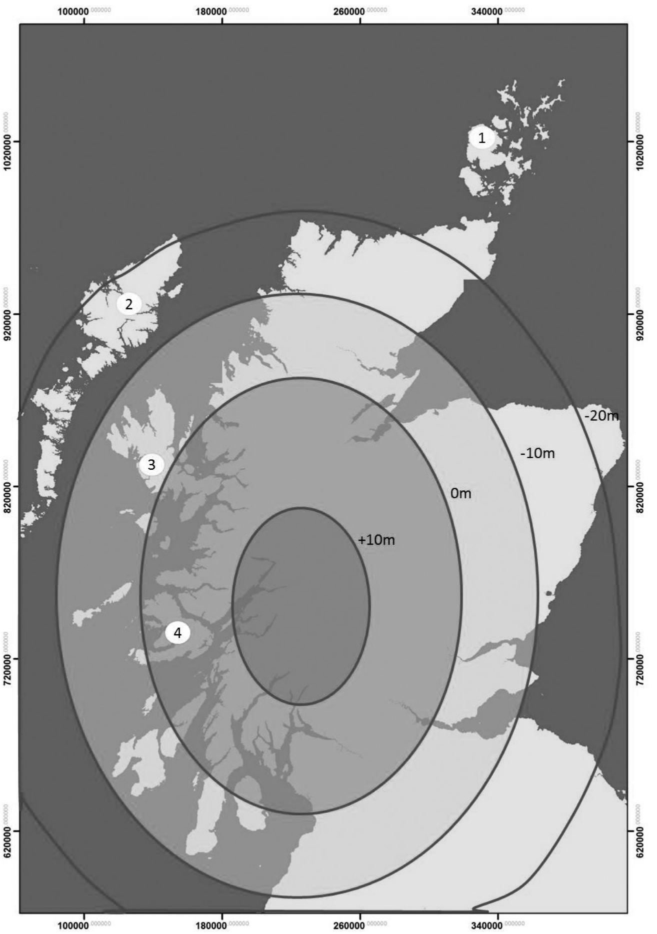


Fig. 4.7 Isobase model to show the relative height of the Main Late Glacial Shoreline around Scotland. The 0 m isobase corresponds with the height of relative sea-level today. 1. Orkney lies outside the –20 m isobase indicating that the landscape is submerging and the shoreline lay at least twenty metres below present sea-level; 2. the Western Isles, the shoreline occurs between 20 m and 10 m below present sea-level; 3. the Isle of Skye, to the west the shoreline lies below present relative sea-level and to the east it occurs above; 4. in Mull the shoreline is up to 10 m above present relative sea-level. Image: Richard Bates, University of St Andrews and Sue Dawson, University of Dundee

While data to build sea-level index points have been collected in many places around Scotland, they are lacking from many of the peripheral areas. These are precisely the parts of the country where submerged sites and landscapes may occur. It is therefore necessary to use modelling to get an idea of the past sea-level history in these locations. Information relating to past relative sea-level change, deglaciation, and the glacial recovery of the country have all been combined to produce models of the changing coastlines of Scotland in the Holocene. These models are useful for providing an idea of the scale of relative sea-level change around Scotland, but they do not always provide the precise detail relating to the nature of change in specific locations that is necessary to discuss possible impacts on individual human communities. For that, it is necessary to use empirical evidence collected from the areas in question.

One such area is the archipelago of Orkney which has been settled since the Early Holocene and is known for its Neolithic, and more recent archaeology. As Orkney lay

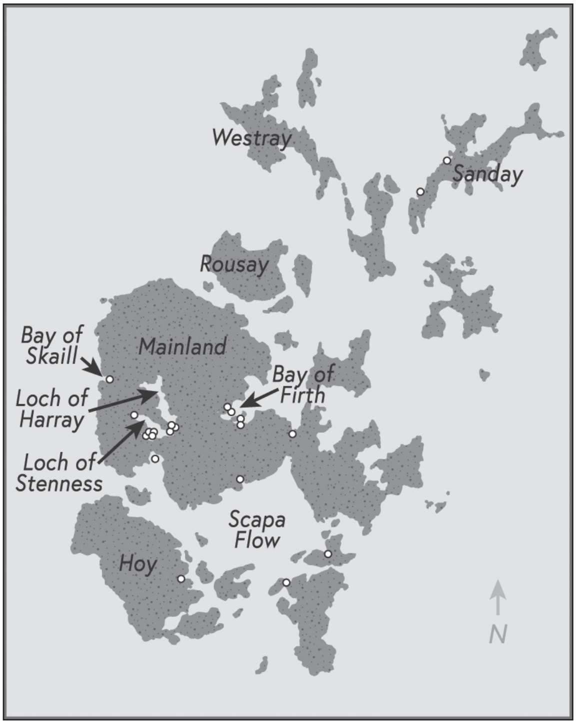


Fig. 4.8 Orkney, Scotland: locations from which core samples have been taken for analysis of changes in past relative sea-level. Image: Rhona Jenkins

towards the edge of the ice sheet, it has not undergone the same isostatic recovery as those areas that lay nearer to the centre of the ice, with the result that relative sea-levels around Orkney have been steadily rising since the end of the last Ice Age. Archaeologically, it is important to consider how the inundation of coastal lands might have impacted on the prehistoric population of Orkney. The models suggest considerable loss of land in the period between 11,000 BP and 7000 BP (Sturt *et al.* 2013), but it is necessary to use precise information relating to the archipelago in order to validate this and provide detailed interpretation relevant to local communities. Since 2005, the Rising Tide project (see p. 79; 162) has worked to construct a number of sea-level index points and combine them to provide a more detailed sea-level history of Orkney.

Sediment coring and analysis has been used to create SLIPs in key locations relating to the principal archaeological sites in Orkney. Locations include salt marshes, coastal lagoons, and shallow marine embayments (Fig. 4.8). Diatoms, foraminifera and ostracods were analysed, and the changes dated by radiocarbon assay. The resultant dates provided SLIPs which could then be combined to produce a sea-level curve (Fig. 4.9) and give a picture of the changing topography of central Orkney throughout the Holocene as relative sea-levels around the islands rose. In particular, work has

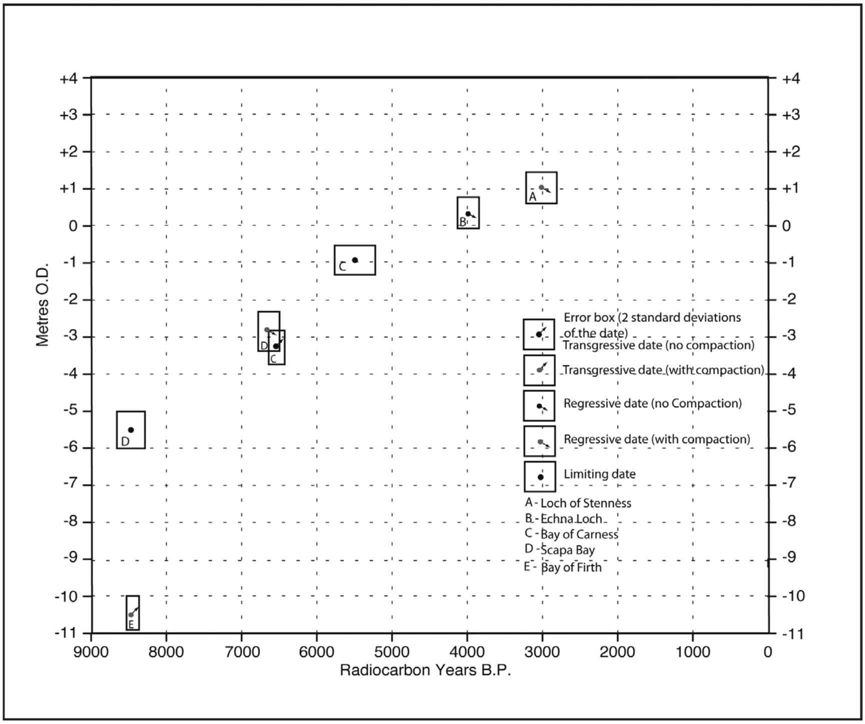


Fig. 4.9 Holocene relative sea level curve for Orkney. Dates are reported from Bates et al. (2013a) (A, B, E), de la Vega-Leinert et al. (2012) (C) and de la Vega-Leinert et al. (2007) (D). Image: Sue Dawson, University of Dundee

focussed on two key areas: the Bay of Firth (Bates *et al.* 2013a), and the Loch of Stenness (Bates *et al.* 2016).

The Bay of Firth lies at the heart of the islands. A number of archaeological sites including Early Neolithic settlements lie around the shores of the bay (Richards and Jones 2016) and in addition there are local stories that talk of underwater finds between the islands here. Sediment cores have been extracted from four locations and used to provide detail of the topographic and sedimentological history of the bay (Bates *et al.* 2013a), the change to freshwater conditions in the cores has been dated, and these have been combined with data from sonar and seismic survey (Pl. 6) to construct a model of the changing conditions from the Mesolithic to the Bronze Age (Pl. 5a). The most notable elements of this research include detail of the changing intertidal zone; in the early millennia, as relative sea-level rose, there was a considerable intertidal zone and this would have been crucial as a productive resource area for early settlers. Over time, as relative sea-level rose, the balance of the intertidal zone changed. Variation in the processes of inundation are also evident as a sequence of barriers towards the sea held back inundation from the small bays and lochans that lay to the landward side. Each

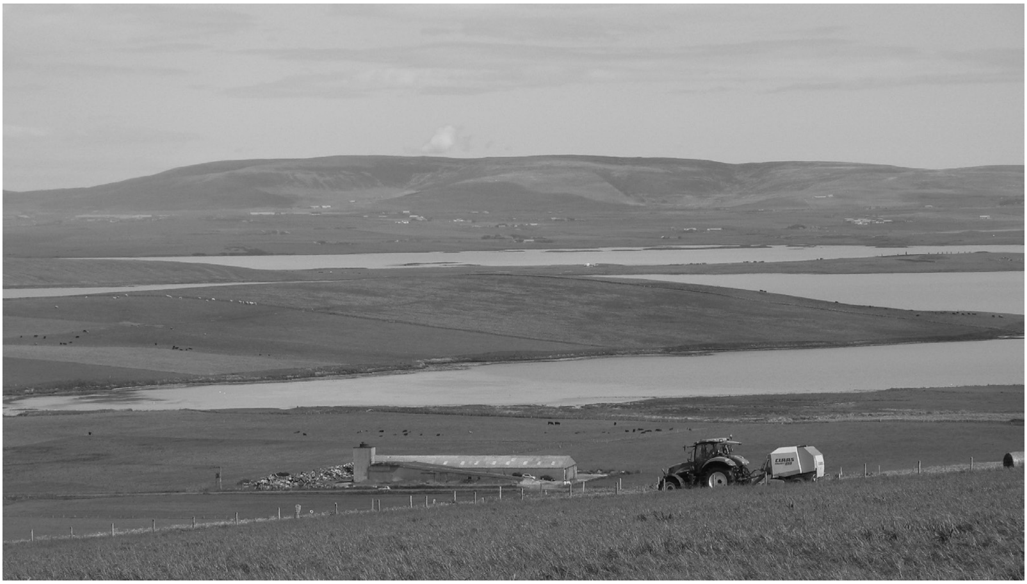
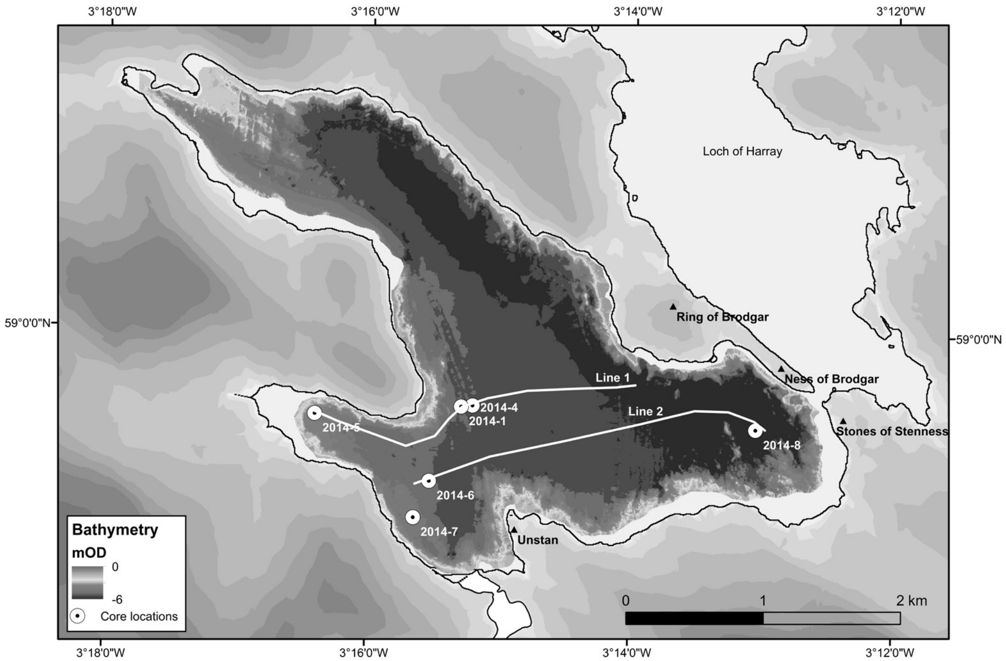


Fig. 4.10 Orkney: the lochs of Stenness (foreground) and Harray

barrier breached separately to the others, meaning that it is not possible to extrapolate marine inundation across the bay.

Various rocky features, potentially archaeological sites, were recorded on the seabed during the survey of the sea floor, but it has not been possible to verify their anthropogenic nature (Pl. 7). Instead, work has focussed on reconstruction of the ancient land surface conditions. Detailed information relating to the dates of inundation has been compiled in specific areas, in order to assess whether these were likely spots for human activity and the period when they would have been available for the communities who lived in the area. By investigating the landscape context in this way, it is possible to narrow down areas that may hold archaeology (Bates *et al.* 2013a).

To the west of the Bay of Firth lies the Loch of Stenness which borders the famous Neolithic sites that help to make up the Heart of Neolithic Orkney World Heritage site (Fig. 4.10). Included in the Neolithic sites here is the Ness of Brodgar, where substantial stone structures are currently under investigation (Towers *et al.* 2015; Card 2018). The Loch of Stenness itself is connected to the sea through the narrow Brig of Waithe at its southern end, and an understanding of the changing conditions and levels of water in the loch is crucial to providing the full landscape context and human interpretation of the monumental sites. Work on the sea-level history of the loch includes sonar and seismic survey and the analysis and dating of sediments from six cores (Fig. 4.11; Bates *et al.* 2016). It illustrates a sequence of dramatic change whereby higher water levels and a freshwater loch existed at the start of the Holocene. Loch levels dropped around 6000 years ago, only to rise with the incursion of the sea around 5700 years ago, and continue rising to reach present levels around 3500 years ago (Fig. 4.12). This means


3°18'0"W
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Loch of Harray
Ring of Brodgar
Ness of Brodgar
Stones of Stenness
Unstan
Line 1
Line 2
2014-4
2014-1
2014-5
2014-6
2014-7
2014-8
Bathymetry
mOD
0
-6
Core locations
0
1
2 km

Fig. 4.11 The Loch of Stenness, Orkney: bathymetry derived from detailed sonar survey, showing the location of seismic sections and core sites. Image: Richard Bates, University of St Andrews

that when work started at the Ness of Brodgar, some 5500 years ago, the loch had only recently turned brackish and moreover the neck of land on which the monuments were sited was likely to have been at least twice as wide as it is today. Transformations of this nature are likely to have been significant in the life of the sites (Wickham-Jones *et al.* 2016), but would not be picked up in such precise detail by broadscale modelling.

The combination of broadscale and high-resolution modelling used in Orkney provides a powerful tool with potential to aid understanding of the relative sea-level history of Scotland and to begin to consider the possible impact on the early population of living within such a dynamic environment. Further studies are providing detail of other areas in the archipelago, and each area that is investigated also helps to increase the accuracy of the overall picture.

Northwestern Australia

The history of past change in relative sea-level in northwest Australia is based on the modelling of data across the area at a scale that provides a higher resolution than the Scotland-wide profiles discussed above, but is more general than the Orkney-specific survey (Ward *et al.* 2016). This research is essential for an understanding of the early

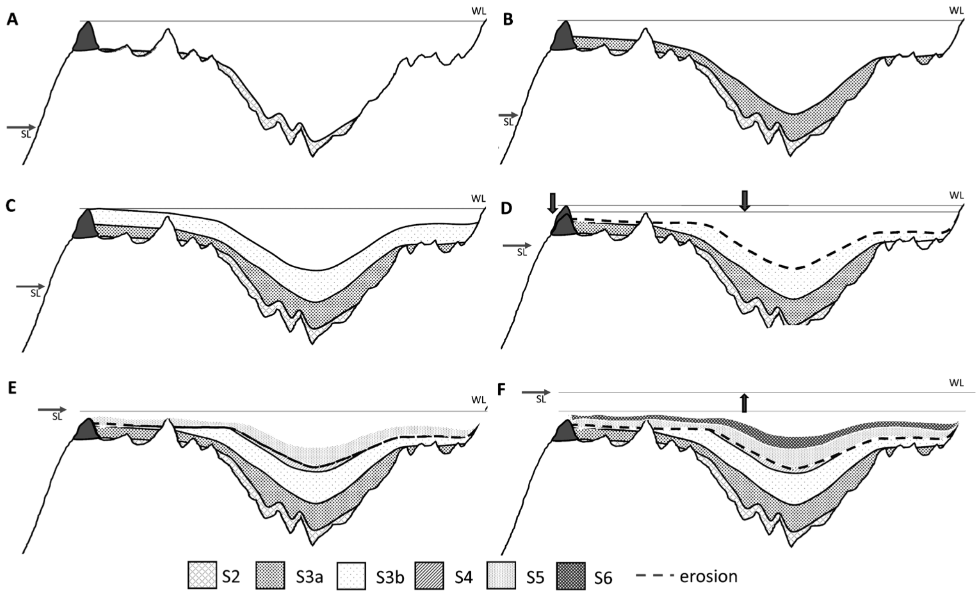


Fig. 4.12 The Loch of Stenness, Orkney: sections showing sediment accumulation and changing conditions. A–C: 13,000 BC–4000 BC – freshwater; D: Sometime between 5000–4000 BC; erosion lowered the rock lip that holds back the loch. Water levels fell to the height of the lip, and the relative sea-level was still lower; E: c. 3700 BC – rising relative sea-level reached the level of the lip and brackish water entered the loch; F: relative sea-level rose to present day height and the area of the loch increased. Image Martin Bates, University of Wales, Trinity St David and Richard Bates, University of St Andrews

human colonisation and settlement of the area. Palaeoenvironmental information has been integrated with the models of previous relative sea-levels and topography in order to investigate the archaeological potential.

This research investigates three island groups: the Montbello Islands; Barrow Island; and the Dampier Archipelago. In addition to a straightforward history of past sea-level rise, the changing resource base, with implications on productivity, has been under consideration. For example, zooarchaeology records illustrate the change in the fauna of the Montebello Islands from inland terrestrial species to coastal and marine species.

The island groups under consideration all sit on the continental shelf and comprised dry land prior to the last marine transgression which was most marked around 18,000 years ago (Pl. 8). A combination of sea-level information and geology/geomorphology indicates the presence of a low plain running westwards to the coast, with rugged hills up to about 300 m high where the islands exist today. Field research has recorded various past shorelines, now submerged, indicating that inundation was not continuous.

While the sea-level and topographical history of the area is based on modelling rather than empirical data, it is possible to approach an understanding of changing human settlement through the period. Detailed analysis of the faunal remains from individual sites helps to shed light on local conditions and the wider palaeoenvironment. This particular project notes that reconstructions of palaeo-tides and currents are as important for an understanding of past human behaviour and adaption as information related to changing topography. Furthermore, investigation of fossil shorelines is not only providing data relating to the past changes in relative sea-levels but, through the recovery of stone tools and shell debris, it also yields direct information on human activity. This project is a good example of the integration of archaeology as a geoscience.

5. The mechanics of site submergence and preservation

Inundations vary in character and the survival of a site during any marine inundation is dependent on various interacting factors such as the water energy and speed of submergence, as well as local geology and topography (Flemming *et al.* 2017a; Masters and Flemming 1983). The type and period of site is also relevant. It is important to understand the mechanisms of submergence and preservation because of the way in which survival biases both the discovery of sites and our final interpretations of the data we retrieve (Flemming 1983).

Rates of sea-level rise

Sea-level rise may be slow or fast – and anything in between. In practice, over a period of time, such as the Early Holocene in the UK, sea-level rise has not been uniform, but rather it has varied from periods of potentially catastrophic rapid rise, usually over a short period of time, to periods of gradual creeping rise that took place over a longer period.

Nevertheless, it is difficult to find evidence that even the most catastrophic periods of rapid sea-level rise resulted in the overnight drowning of settlements. For example, the final drainage of Lake Agassiz, formed of meltwaters in North America, which took place around 8,400 years ago has been linked to a rapid rise in global sea-levels of 0.4–2.8 m (Dawson 1992; Teller *et al.* 2002) and yet no evidence for this has been discovered on land in the British Isles. Periods of prolonged bad weather, which might well include coastal flooding, posed a much greater threat to those living by the sea. As the high tide increased during a period of rapid rise, people still had time to adapt, though the remains of past settlements might slowly become inundated or eroded (see the Nunalleq example, p. 171). In contrast, periods of much slower sea-level rise have been modelled at other times (Lambeck and Chappell 2002). On occasion, it is possible that sea-level rise was so slow as to be barely discernible to those living along the coast, except from remembered stories relating to the landscape that grandparents once knew. Where this happened, a site might be inundated so gradually that there is little disturbance of the material remains. Gentle inundation can also bring the deposition of considerable amounts of sediment, resulting in the preservation of material, albeit well-hidden below the final seabed.

The Storegga tsunami

Just over 8000 years ago a massive underwater landslide occurred to the west of Norway, displacing approximately 5600 km3 of material. This event is known as The Storegga Slide, and it triggered a tsunami of catastrophic proportions which impacted across the coastal area of the northern North Atlantic, on the Norwegian coast and around the northern and eastern coasts of the UK, within hours (Long *et al.* 2016). Various causes have been postulated for the slide including post-glacial settlement of the earth's crust, methane release, and earthquake; most likely it resulted from a combination of factors (Bryn *et al.* 2005).

The tsunami has been dated using organic elements caught up in the deposits it generated. These include mosses which must have died within moments of the tsunami hitting them and which yielded very precise dates of 8120–8175 BP, placing the tsunami at the heart of the climatic downturn known as the 8.2 ka cold event (Bondevik *et al.* 2012). Research indicates that the tsunami occurred in the autumn, due to the analysis of organic elements within the sediments, such as fish bones and a cherry stone (Bondevik *et al.* 1997; Dawson and Smith 2000).

Research on the tsunami has included the analysis of sediment deposits in many locations around the north and east coasts of Britain and the coasts of Norway. From this it is possible to calculate that, in Shetland, the sediment reached 20–25 m above the sea-level at the time (meaning that the wave itself must have been higher). Although it would have been of less height further south, it has been suggested that the tsunami was a significant factor in the flooding of the final shores of Doggerland (Weninger *et al.* 2008).

In fact, the disappearance of Doggerland had started around 20,000 years ago with the initial rise of sea-levels, towards the end of the last glaciation, though it did not speed up until deglaciation around 12,000 years ago (Wickham-Jones forthcoming). Nevertheless, the impact of the tsunami on coastal dwellers should not be underestimated. Archaeology indicates that the inhabitants of the fringes of northwest Europe at the time included many who may have relied on the coast and sea for resources. Not only would the tsunami have been devastating to those living along the shore, but it would have upset the eco-system for years to come. The impact would be emotional as well as physical and it may well have taken decades, if not longer, for communities to recover. Low-lying coastal lands would certainly have flooded temporarily, and some must have disappeared for ever.

Ironically, though the Storegga tsunami comprises perhaps the best-known example of the impact of inundation on the northern coastal landscape, archaeological deposits relating to it have not yet been found. Investigation of historic tsunami locations suggests that the turbulence and high energies associated with a tsunami mitigate against the survival of cultural remains impacted by the event in prehistory (Wickham-Jones 2002).

Relative sea-level rise is not a continuous phenomenon. Not only does the rate change over the years, but it can be an intermittent process involving periods of standstill. Those who live with sea-level rise have to be adaptable, and for many of our ancestors change in their landscapes from processes such as this was the norm rather than the exception (Wickham-Jones forthcoming). Present day attitudes to relative sea-level change are affected by the fact that we have lived through relative stability in the world for the last few centuries.

Other changes in relative sea-level could be sudden and even catastrophic. The impact of the Storegga tsunami, around 8200 years ago, is well researched (Bondevik *et al.* 2003; Dawson *et al.* 1988). In Shetland, it is estimated to have run up to 20–25 m above sea-level at the time (see above). The tsunami only brought a temporary change in sea-level, other events were more permanent. Earthquake damage leading to long-term changes in sea-level have been recorded as the catalyst for submergence at several sites such as Port Royal in Jamaica (Hamilton 1988), and Pavlopetri in Greece (Henderson *et al.* 2011). While the submergence of Port Royal has been ascribed to a single event, that of Pavlopetri is more complex, related to a series of tectonic movements taking place in the eastern Mediterranean over the last 5000 years.

Clearly, the rate at which local waters flood across a site is crucial to matters of preservation or destruction once it lies beneath the waves. The situation is more involved than this, however.

The energy of the waters

The sea is a dynamic environment. The energy of the waves; the energy of the currents; tidal range: all can vary considerably, and all play a part in the survival of material under water.

Wave energy depends on several factors: the fetch, or distance across the ocean which the waves have travelled, longer fetches allow them to acquire more energy; the prevailing wind which helps to add or detract from their strength; and the topography and nature of the seabed surface over which they roll (Fig. 5.1). In general, a lower gradient in the offshore zone and beach will work to lessen wave action. The combination of these factors means that wave energy can vary considerably through time and from place to place.

Fig. 5.1 Waves can exert considerable energy on a shore

Currents, also, depend on several factors. They are affected by water movement, the wind, density differences in the ocean, tides, air pressure, and the topography (including transient features such as sandbars). There are many different types of current, varying from the grand scale oceanic currents, to localised rip currents, but the intensity of a current is not necessarily in proportion to its size. Present day currents can be measured, but in order to understand the currents of the past it is necessary to undertake modelling that takes all of the relevant factors into account as far as possible. Because of the potential for variation in weather, landscape and other elements, it is not possible to assume that the currents of the past were equivalent to those of today. Gaps in our knowledge relating to these factors also mean that our information about past currents can never be precise. The interpretation of ancient currents, too, is a model.

Although the tides and tidal range seem immutable today, they too have varied considerably in the past and modelling the tidal environments of prehistory requires consideration of variables such as lunar activity, sea-level change and isostasy (Uehara *et al.* 2006). The general conclusions of tidal modelling suggest that the greatest changes in the tides of the northwest European shelf occurred prior to 10,000 years ago, nevertheless, tidal action is always a relevant consideration for the survival of underwater archaeology and landscapes.

Local conditions and topography

The location of a site is an important consideration for any investigation of site preservation. Factors such as geology and topography can all impact on site survival.

Geology, very generally, hard rocks will resist erosion from the sea while softer rocks crumble (Fig. 5.2). But, of course the process is much more involved than that. Depending on the energy of the waters, rising sea-levels may impact less on the survival of the coastline itself than the impact of periods of standstill. It is the repeated impact of the waves on a stretch of shore over centuries that can result in actual erosion. For this reason, and perhaps ironically, the coast itself may be at more risk in times when relative sea-level is rising slowly. Inundation, especially when rapid, may drown the land and yet preserve it under water.

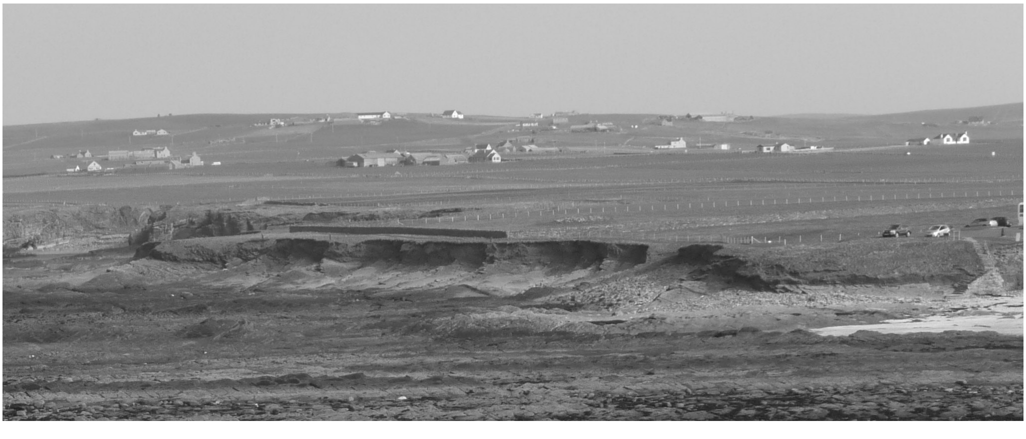


Fig. 5.2 Birsay, Orkney: the impact of wave action on alternating bands of hard and soft rock can be seen clearly in this view

Geology is rarely a simple factor, but a clear understanding of the different rock types along the shore is necessary in order to appreciate the development of the submerged landscape. In some cases, old coastal features may have been preserved, in other cases softer rocks may have crumbled and led to the formation of sediment. Sediment itself may have been washed away and deposited elsewhere. The location of archaeological material in relation to the geology is of crucial importance in the way in which it will be impacted by inundation.

In some cases, archaeological remains may already be embedded in softer deposits such as peat or coastal sediments. These will help to provide protection during inundation. In high latitudes, the ground may be frozen, also assisting protection in the event of submergence.

Topography, the location of a site both before and after inundation, also affects the condition in which it will survive. Sites that are exposed to the ocean, or on a headland, will tend to be much more vulnerable to erosion. Sites that lie in the lee of an island (Fig. 5.3), or within a group of islands, may survive inundation relatively intact, though they might also be more prone to burial under seabed sediment afterwards. Estuaries, beaches as opposed to cliff lines, lagoons, and salt marshes: the multitude of coastal features each create different conditions for sites along a stretch of shore.

Coastal barriers can impact on the survival of the coastal archaeological record even when sea-level rise is a relatively continuous, steady, process over a number of years. For example, the existence of a coastal barrier, such as a sand bar or rocky shoal offshore, can hold back the sea so that coastal lagoons and flats remain unchanged long after the sea-level along adjoining stretches of coast has risen well above their height (Fig. 5.4). The sea will only submerge the sites within the barrier once the barrier is breached or removed. In many cases where this occurs, the final breaching of the barrier will be a relatively traumatic, sudden event, often with erosive power. For this reason, when reconstructing the development of the coast in any one location, it is important to examine the topography and use specific data, drawn from appropriate sites, rather than generalised models which assume a uniform gradient between sites. The barriers that once held back the sea may have long been eroded away.

Detailed information relating to coastal conditions is particularly important for archaeologists who are concerned with past human communities and the specific world within which they operated.

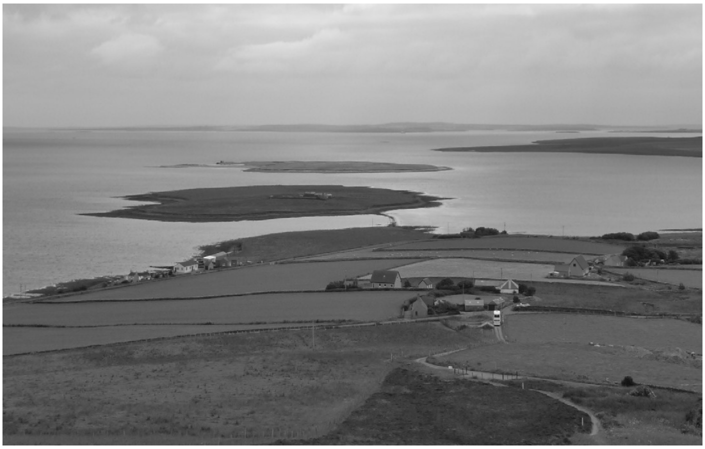


Fig. 5.3 Islands provide shelter for submerged sites that may lie in their lee. The Bay of Firth, Orkney

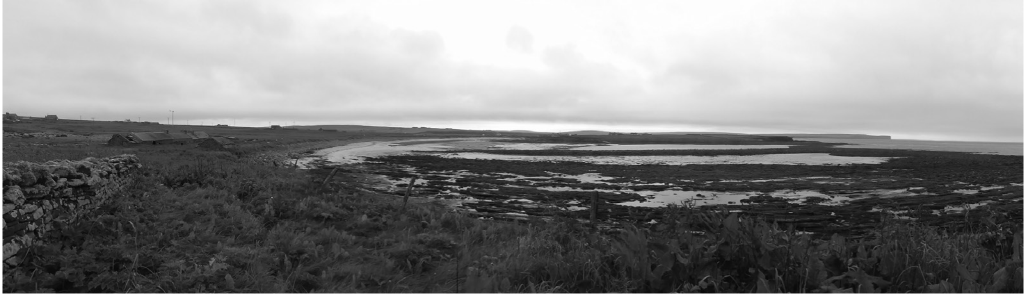


Fig. 5.4 A rocky offshore barrier can protect sites that lie behind it. This particular site lies at Pool in Orkney, where a rich multiperiod site has been preserved behind the barrier

The archaeological sites themselves

In addition to the variation along individual stretches of coastline, there is considerable variation amongst archaeological sites and this, too, has an impact on the likelihood that a site will survive inundation.

Age is one clear factor: older sites tend to be more fragile than more recent material, and may, already, have been subject to processes of erosion and decay. There are, nevertheless, other relevant factors relating to building material and function. Different types of site might include substantial foundations: the buildings at Port Royal included stone, brick and timber remains, each of which reacted very differently to earthquake and inundation. Built structures contrast greatly with hunter-gatherer remains which may comprise little more than the ephemeral traces of hearths and tent stances (Fig. 5.5). Urban centres, like the remains of Thonis-Heracleion at the mouth of the Nile, tend to be more robust, while cemetery sites can be particularly fragile. The site at Atlit Yam, off the Carmel Coast of Israel, included both an early farming village dated to between 7200–6500 BC, and the burials of 65 skeletons (Galili and Rosen 2011). Industrial material, meanwhile, can occur anywhere and varies greatly in nature. All will react differently to submergence. A clear understanding of the types of site that prevail in any locality is necessary for work on the submerged landscape of that area to be archaeologically relevant.

Even within one type of site there is scope for differentiation. The condition of a site can be key to the preservation, or otherwise, of the remains. An active site will leave a very different archaeological footprint to that of a site that has been long abandoned. Newly abandoned sites can deteriorate relatively quickly and are vulnerable to inundation, but once stasis has been achieved then the surviving remains become more robust and preservation, both below and above water, will be improved. Existing archaeological material is more likely to be buried within sediment, and, where the sediment is resistant to erosion during submergence, this can help to preserve the remains. The inundation of existing archaeological material is thus a very different matter from the inundation of locations where ongoing human activity has been abruptly terminated. In most cases, existing populations are very aware of the problems caused by rising sea-levels, so that action, such as the abandonment of vulnerable areas is countered by the rebuilding of facilities further away from the sea. In the Yukon-Kuskokwim coastal region of Alaska, the Yup'ik people have moved their settlements away from

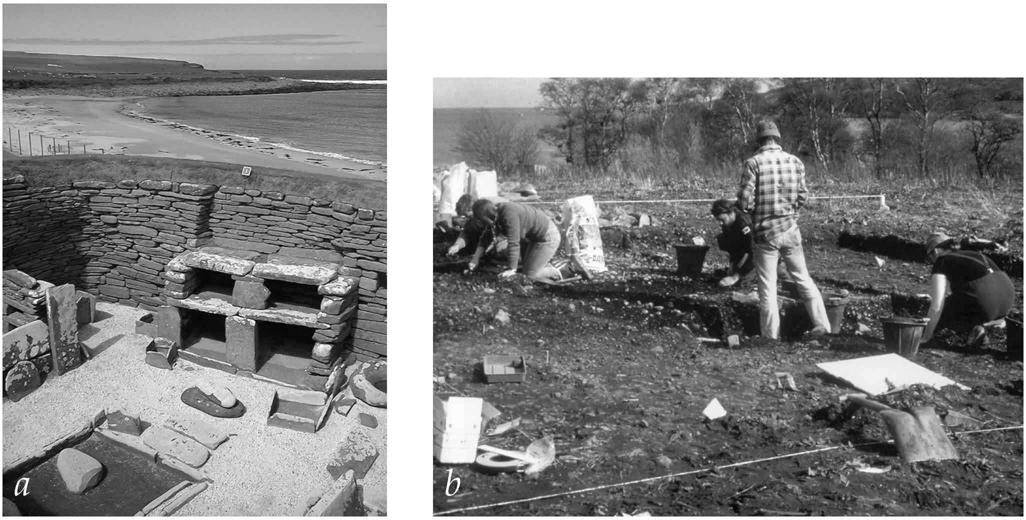


Fig. 5.5 The nature of archaeological sites varies, and this brings much to bear on likely survival after submergence: a) the Neolithic stone structures of Skara Brae will be more robust than b) the ephemeral remains of the Mesolithic site at Kinloch, Rùm. Skara Brae image, Raymond Parks

the sea in order to contend with steadily rising relative sea-levels. Unfortunately, today, the archaeological sites created by this move have, themselves, become vulnerable (Fig. 13.3; Knecht 2014). In other cases, inundation may occur without warning: as at Port Royal, in Jamaica (Hamilton 1988). In general, sites, of any sort, will be most fragile in the period immediately preceding and following submergence, as a local surf zone develops and impacts on the archaeological material.

It is clearly necessary to tailor underwater survey to the specific types of site likely to be encountered (Flemming 1998). In order to work at the correct scale and increase the chances of site recognition, it is important to integrate understanding of site type and age with that of local conditions and geology.

Case studies

Tybrind Vig: The site that should not be

Hunter-gatherer sites rarely comprise substantial built remains, they are usually ephemeral and can be hard to locate on land, never mind underwater. The existence of a substantial hunter-gatherer site at Tybrind Vig in the Danish Little Belt with well-preserved organic remains was therefore something of a surprise, though divers had been recovering artefacts from the site since the late 1950s (Malm 1995). Excavation took place in the 1970s and resulted in the recovery of unusual detail relating to hunter-gatherer life, including fishing traps and equipment, dugouts and paddles, as well as bows (Andersen 2011; 2013). The original archaeological surfaces were not well preserved, but the excavators were able to recover considerable detail relating to settlement activities, and in more recent years, further excavation has uncovered burial remains (Pl. 9; Uldum 2011).

The site at Tybrind Vig is dated to around 7500 BP (Ertebølle Culture) and lay at a depth of *c.* 3 m. When inhabited it lay on the coast, at the mouth of a small river; the rise in relative sea-levels here since the end of the last Ice Age has been slow and served not only to drown it, but also to bury the archaeological remains under soft marine sediment. This resulted in the creation of anaerobic conditions in which the absence of oxygen has resulted in the remarkable preservation of evidence such as textiles, the decoration on wooden paddles and the residues of food remains on pottery. The recovery of this level of data from a hunter-gatherer site is very unusual and a clear demonstration of the way in which the results of archaeology in submerged landscapes can add considerably to that already evidenced by terrestrial archaeology.

Tybrind Vig is significant not only for the remains that were preserved here, but also because it played a key role in the recognition and excavation of underwater sites (Pl. 10; Andersen 2013). Prior to the work at Tybrind Vig, underwater archaeology tended to focus on shipwreck sites so that the techniques of investigation were rarely regarded as relevant for submerged prehistoric material. Work at Tybrind Vig demonstrated that it could be necessary to extend the rigours of settlement excavation on land to the underwater realm and that the results could be well worthwhile.

Orkney: The sites that should be there

The archipelago of Orkney, off the north coast of Scotland, is known for its prehistoric archaeology, including the well-preserved remains of stone-built Neolithic houses and tombs. Rising relative sea-levels since the last Ice Age have resulted in considerable land-loss which only ended around 4000 BP when relative sea-level reached present-day height (Bates *et al.* 2013a; 2016). Nevertheless, research around the islands has yet to record definite submerged archaeological sites, despite anticipating suitable preservation conditions, due partly to the existence of stone buildings on land.

One reason for this is that the bedrock substrate in Orkney is exposed across much of the underwater zone leading to rocky underwater landscapes in which pockets of sediment occur only in calmer areas. Around much of the archipelago, stronger currents bring high energy waters that mitigate against the preservation of material underwater. In addition, given that building materials in prehistory drew on the naturally occurring slabs of bedrock, it has been difficult to distinguish between the local rocky background and submerged anthropogenic structures. Even in areas where local currents are weaker, the predicted collapse of stone walling after abandonment and during submergence has obscured possible sites underwater (Bates *et al.* 2013a). Nevertheless, potentially interesting features comprising mounds of stone have been identified and work is ongoing to distinguish between naturally occurring piles of stones and the collapse of humanly-built structures (Pl. 11). One way to approach this has been to record stone features in the intertidal zone (Pl. 12). Examination of the partial decay and collapse of this material can help with the recognition and interpretation of potential anthropogenic material underwater (Bates *et al.* 2013a).

The work in Orkney is significant because techniques such as those developed here have relevance for other coastal areas around the world where the submerged environment is not as favourable to the preservation and recognition of prehistoric sites as the calm, relatively low-energy, waters of the Baltic that have served to preserve sites like Tybrind Vig.

6. Methodologies I: Remote sensing and sediment analysis

Integration is key

A wide suite of techniques is available for the study of the submerged landscape and, with the constant development and refinement of equipment driven by commercial interests such as those of the oil industry, new and better practices come into play on a regular basis. It is, thus, important to keep in touch with research. As is now commonplace in archaeology, successful studies involve the integration of several techniques. Remote sensing can, for example, be ground-truthed by sediment coring and analysis, and further detail may be added from a diver survey.

Despite the obvious need for sophisticated equipment and analysis in submerged studies, it is also important to remember that all good archaeological work should start with a desktop survey. There may well be reports that cover previous work in the area or on similar sites and landscapes. Other desktop resources including archives and aerial photographs are covered later in the next chapter.

Remote sensing

The development of geophysics for remote sensing below the surface of the land has become an important part of site prospection in terrestrial archaeology. Remote sensing, from different platforms, is also necessary to acquire information about the submerged landscape and underwater sites (Firth 2010).

Bathymetric survey: Sidescan and multibeam sonar

Although the seabed does not necessarily relate to the pre-inundation land surface, it does provide a good starting point for study of the ancient landscape prior to sea-level rise. Techniques of bathymetric survey using acoustic devices are thus useful sources of basic information. They provide a visual picture of the seabed, rather like a contour map, which can be used to highlight various features at different scales. These may relate to significant elements such as possible pockets of preserved sediments or outcrops of rock. They provide a useful point to begin the interpretation of landscape development and can also help with the identification of material that may be of anthropogenic origin such as shipwrecks, ballast mounds, or submerged sites.

Bathymetric maps vary from country to country. Around the UK, the UK Hydrographic Office has released some high resolution bathymetric surveys, some of which are available through Google Earth. In many places, however, the resolution of existing bathymetric survey is not high enough to identify the features that are of use to archaeology, so that new surveys, tailored to specific research questions, are needed. It is also often the case that archaeology is concerned with waters that are too shallow for conventional survey craft so that individual surveys, operated from vessels with a shallow draft, have to be undertaken.

Sonar (Sound Navigation and Ranging) survey techniques make use of the enhanced properties of water for the passage of sound, in order to generate acoustic reflection from the seabed by transmitting sound pulses and measuring the strength of the return as they are bounced back to the transmitter. Essentially, it works on the principle that a stronger signal will be returned from features that protrude above the sea floor, while depressions or sunken features will return a weaker signal. A simple sidescan system transmits its signal in the shape of a fan that sweeps across the sea floor to either side of the survey vessel which is carrying the transmitter or 'towfish' (Pl. 13). It builds up a map of the signal returns in which projecting features are highlighted as lighter areas. In reality, the process is more complex than that because of factors such as the density of seabed features, rock will affect the signal in a different way from sediment, for example. Another complication lies in the fact that features that project above the sea floor create shadows because the signal comes from one, central, point. Nevertheless, as the survey vessel moves forward so the signal from the towfish can be used to build a two-dimensional image of the sea floor in which higher areas and basic differences in texture are presented visually (Fig. 6.1).

Multibeam sonar uses a more refined system of transmission and analysis of the sound pulses in order to clarify some of the uncertainties that beset the interpretation of sidescan results. The single sound beam is broken into multiple narrower beams, and the time taken for the acoustic signal to bounce back is recorded, allowing a multibeam survey to provide a more three-dimensional image of the seabed which includes depths (Pl. 14).

Both systems rely on accurate D-GPS location to build their images of the sea floor above which they are travelling.

Seismic profiling

Given that the contemporary seabed does not always correspond with the topography of the pre-submergence landscape, techniques are necessary to 'see below' the sea floor and characterise the deposits. Sub-bottom profiling, using seismic remote sensing and often called chirp because of the acoustic techniques used, is the most common method (Faught 2014a).

In order to build a seismic profile, low frequency acoustic waves are sent through the water column, unlike the sonar sound waves these penetrate below the seabed. They continue into the substrate and are reflected by the different layers below the surface. As the different properties of sediments and rock structures impact on the reflection and refraction of the acoustic waves, it is possible to analyse the returning sound waves and build a model of the properties of the subsurface (Fig. 6.2).

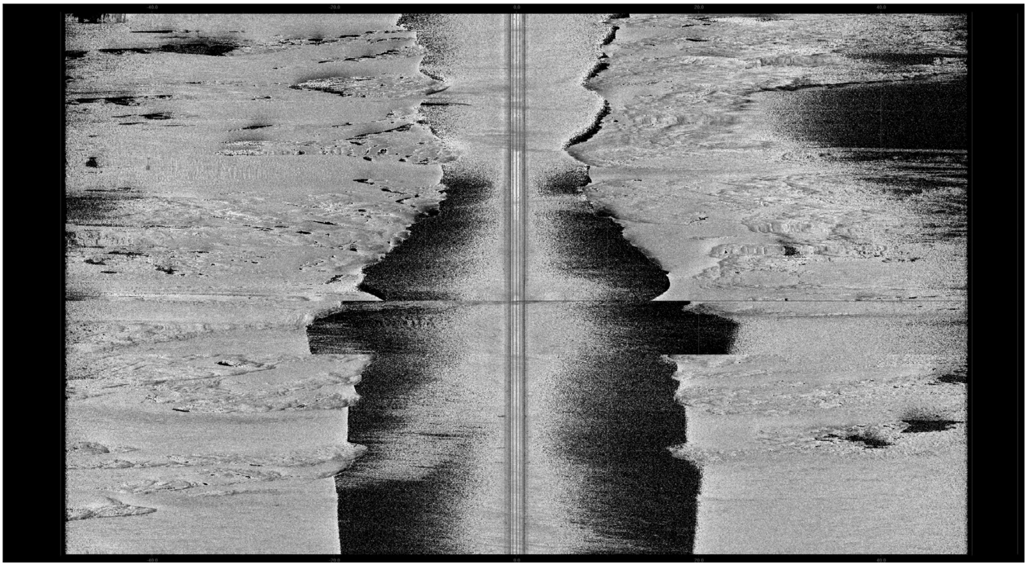
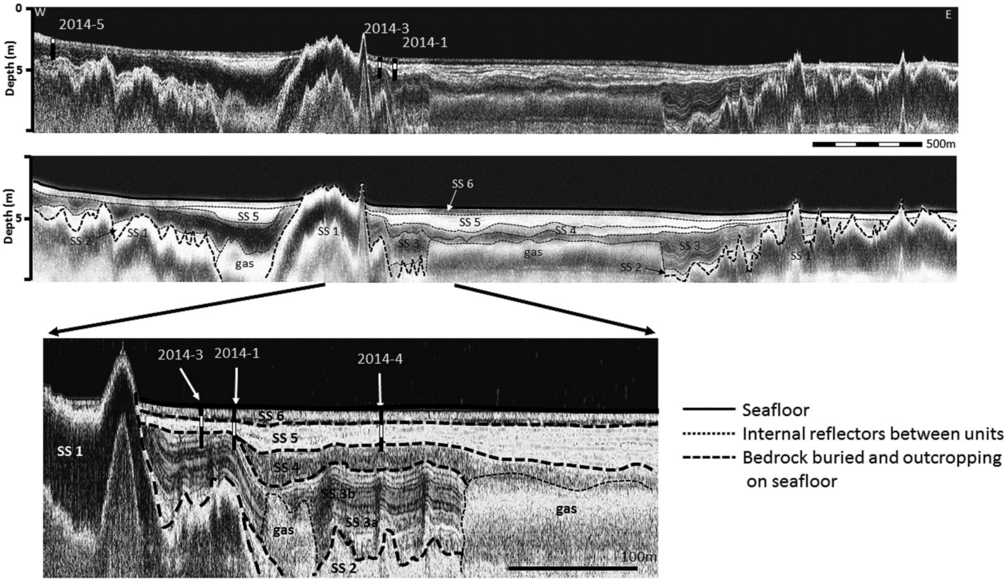


Fig. 6.1 Typical screengrab from a sidescan survey. The central line denotes the passage of the boat. To either side is an area of varying width that denotes the height of the water column at that point. The image to either side of that represents the seabed. Different textures can clearly be seen, and upstanding features throw black shadows behind them. Image: Richard Bates, University of St Andrews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2014-4
SS 1
SS 6
SS 5
SS 4
SS 3b
SS 3a
gas
gas
SS 2
100m
Seafloor
Internal reflectors between units
Bedrock buried and outcropping on seafloor

Fig. 6.2 A typical seismic profile with some interpretation, from the Loch of Stenness, Orkney. Image: Richard Bates, University of St Andrews

The interpretation of seismic data is highly specialised, but it is possible to distinguish different units. For example, decayed organic matter, the build-up of different types of sediment, and bedrock, all produce different signals, so that the resultant seismic picture can be used to provide a detailed image of the different components below the present sea floor. This may then be used to identify possible ancient land surfaces. A seismic profile will often be subsequently tested by coring and the analysis of sediments and it is an invaluable technique for the investigation of old land surfaces (van Heteren *et al.* 2014). Ongoing research is taking place to examine the possibility of using high resolution seismic profiling to distinguish elements of archaeological sites such as hearths or buried timbers, or even artefacts (Grøn *et al.* 2007; 2015).

Autonomous Operated Vehicles (AUVs) and Remote Operated Vehicles (ROVs)

Acoustic and Seismic surveys usually operate from fixed sensors that are towed or mounted on a vessel. They can also be mounted on a variety of underwater vessels including both manually operated ROVs and pre-programmed AUVs (Fig. 6.3). As this technology is of considerable significance to commercial applications such as cable laying or oil exploration, new and more sophisticated vessels are constantly being developed, especially to work in a variety of marine environments. This enhances their application to archaeology which is often undertaken in locations that do not match the conditions of commercial work. In addition to remote survey equipment, ROVs and AUVs are of use in photographic work including both conventional photography and laser photography.

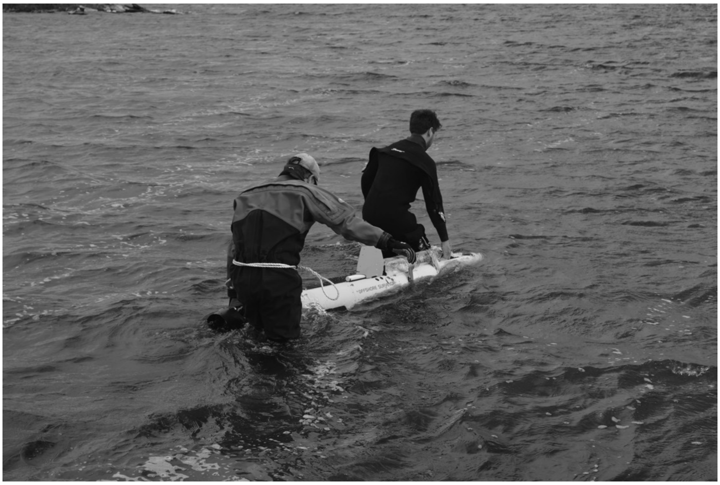


Fig. 6.3 Preparing to launch Freya, an AUV from the Scottish Association for Marine Science and deploy her for archaeological survey in the Loch of Harray, Orkney

Existing data sets

Archaeologists are not the only people to be interested in the properties and dynamics of the seabed, with the result that there are existing data sets that cover large areas of the sea-floor. This research may be undertaken for those who need information about the floor itself, such as companies who will be laying pipelines or cables, or for those who need information relating to the structures below the surface of the seabed. Examples of the latter include oil companies or aggregate extraction companies. Companies such as these have more resources than are usually available to archaeology and they are able to make use of sophisticated equipment that provides high resolution information vital to the success of their industries. In many cases, they are interested in strata that lie considerably deeper than those of archaeological interest, but, in order to collect it, they also obtain data from higher strata that relate to the inundation of previous land surfaces.

Where this data exists, it has sometimes been possible to draw up research agreements so that archaeologists, with their non-commercial interests, can make use of these existing data sets to provide information about the late glacial and early post-glacial landscapes that once existed. This is particularly useful for areas, such as the deeper parts of the North Sea, where the great depths of water and of the seabed sediments means that it becomes very difficult to access the ancient land surfaces below them (Gaffney *et al.* 2007). The Marine Environmental Data and Information Network has been set up to facilitate access to this sort of data (http://www.oceannet.org/).

LiDAR

Submerged archaeological sites and landscapes often occur in nearshore waters that are relatively shallow, and this can pose a problem for acoustic survey vessels which tend to require a deeper draught. It is now possible to use devices that can be mounted on a smaller vessel (Bates *et al.* 2013), but another survey technique that is of particular use in these situations is LiDAR (Light Detection and Ranging).

LiDAR is usually operated from an aircraft (though personal mounted systems are becoming increasingly available), and it makes use of laser light. Pulsed laser beams are fired towards the surface to be surveyed and the equipment measures and analyses the time taken for the beam to return to the sensors in order to build a digital terrain model (often called a DTM) (Pl. 15). LiDAR over land usually makes use of near infrared light, while green light is more commonly used over the sea in order to penetrate the water column (Doneus *et al.* 2013). Careful analysis of the returning LiDAR pulses allows detection of the surface of the water as well as intervening elements in the water such as fish and plankton, all of which help to refine the results.

The digital terrain models (DTM) which result from LiDAR are represented in three dimensions. They can be stripped back to remove 'noise', such as dense growths of seaweed, and this means that they provide a simple, clear image of the sea floor which highlights both potential landscape features and possible sites (Pl. 16). LiDAR has been

Existing data sets and the landscape of Doggerland

The most successful agreement of this type concerns the pioneering work undertaken by Vince Gaffney and his colleagues at the University of Birmingham's VISTA (Visual and Spatial Technology) Centre. Gaffney and the team persuaded Petroleum Geo-Services to provide data from their MegaSurveys of the North Sea, comprising seismic data relating to a large area of land in the southern North Sea (Gaffney *et al.* 2007). This was analysed to provide information about the buried topographical features and palaeoenvironmental conditions of a number of ancient landscapes superimposed over one another. The project publications provide considerable detail relating to the techniques of analysis and the results have been presented both academically and in more popular form (Fitch *et al.* 2007; Gaffney *et al*. 2007; 2009). The significance of this work is threefold: first, it has demonstrated the value of co-operation between industry and archaeology and the archaeological relevance of the data sets; secondly, it has illustrated, very clearly, that the submerged landscape of the North Sea, known today as Doggerland, did not comprise a simple land-bridge; thirdly, and finally, it indicates the extent of landscape preservation under the seabed sediments of the North Sea.

Doggerland has often been spoken of as a land-bridge, but the Birmingham work has revealed a diverse topography including hills, rivers, lakes and marshland. They have also emphasised the extent of Doggerland from the period of maximum emergence around 20,000 years ago, to the centuries immediately before the last vestiges of land disappeared around 6000 years ago (Fig. 1.2a). This was a considerable tract of land that stretched from the north of Scotland to the English Channel. At its maximum extent it was larger in area than many twenty-first century countries. Even with the lower population levels of the time, it is likely to have formed a stable territory for many communities (Fitch *et al*. 2007).

The Birmingham work has been instrumental in advancing the study of submerged landscapes, illustrating the potential of both the research techniques and the results. Further research is now underway to obtain dates and provide a chronological framework for the landscapes revealed and to fill out some of the palaeoenvironmental details including vegetation and fauna (https://lostfrontiers.teamapp.com/). The team is now based at the University of Bradford, and they are developing a range of innovative geoscience techniques which will be discussed below. The ultimate goal, of investigating specific archaeological sites, remains in everyone's minds.

used with considerable success for the survey of submerged archaeology at various scales (Harff *et al.* 2016a). The technique is being refined with the integration of improved and higher resolution equipment and analysis. Techniques like LiDAR may also be combined with sub-bottom profiling, aerial photography, and diver survey in order to build a more accurate picture of possible features (Doneus *et al.* 2013; Sailors and Honda 2013).

Sediment coring for geoscience analysis

Remote sensing is a critical tool for the study of submerged landscapes, but it does not provide hard data with which to build a precise interpretation of the ancient

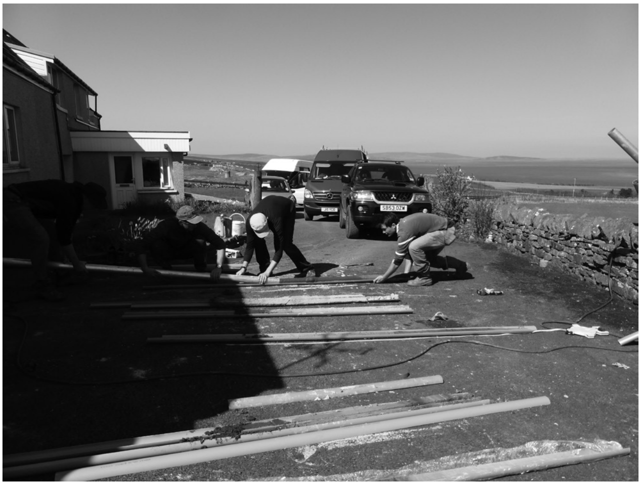


Fig. 6.4 Opening sediment core tubes to reveal and package the environmental sample material inside

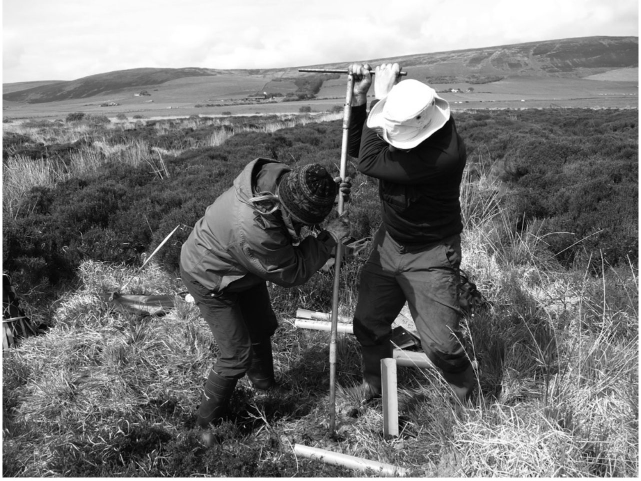


Fig. 6.5 Coring with a Russian corer

world. The visual images that result from remote sensing can only ever be models, and in order to flesh them out with precise information relating to flora and fauna, or the dates at which a landscape existed, it is necessary to obtain data derived from ancient pollen, microfossils and other remains. To achieve this, sediment cores, within which such information might be preserved, are required.

Sediment cores comprise samples of sediment collected within a long cylindrical container (Fig. 6.4) as it is pushed into relatively soft strata such as the bed of a saltmarsh or a muddy sea floor (Frew 2014). In practice, it is not as easy as it sounds because both the insertion and extraction of the core can require considerable force. Nevertheless, many coring techniques make use of manual labour in which a cylindrical or semi-cylindrical metal chamber is thrust into the sediment using a sequence of rods. Two good examples of these are gouge augers and Russian corers. Gouge augers are small in diameter, easier to transport and insert into the sediments, and useful for a preliminary inspection of sediment material, but in general, as their diameter is small, they do not provide samples that are of sufficient size to use for accurate analysis. As they have an open chamber there is also a high possibility of contamination of the sample. The Russian corer has a wider chamber with a flange that serves to close it and protect it from contamination. It holds a larger core which can then be stored in drainpipe ready for transport and sampling (Fig. 6.5). Hand-held devices, such as Russian corers, are of use in shallow water and soft sediments such as coastal embayments or estuaries and on land in areas such as salt marshes or peat bogs (Fig. 6.6).

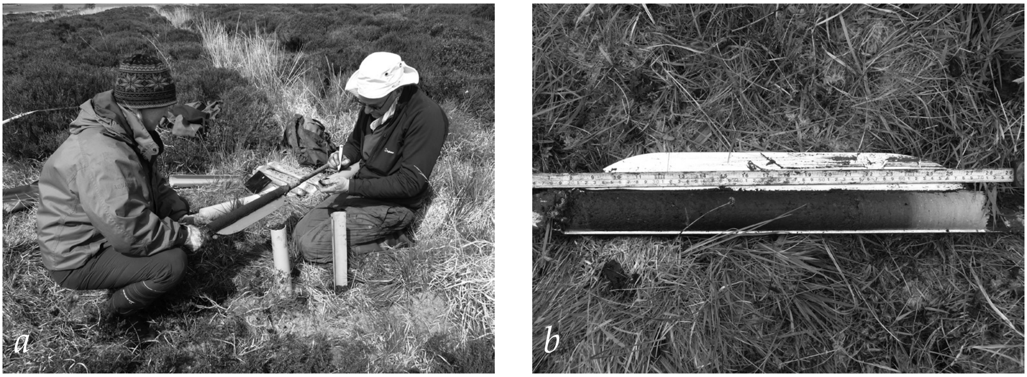


Fig. 6.6 Using a Russian corer: a) recording the core from a Russian corer; b) it is often possible to see clear difference in the sediment

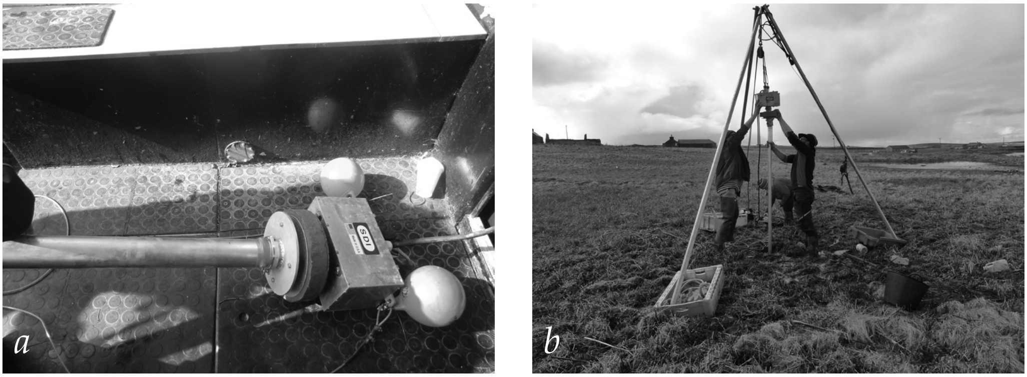


Fig. 6.7 Using a vibrocorer: a) the core motor; b) coring with the vibrocorer

Where the sediments are more intractable it is possible to use a motor to vibrate the chamber, which helps to push it down into the sediments (Fig. 6.7). Vibrocorers are not large and they can be designed to make use of shallow craft and hand-held, or motorised, coring equipment. The use of a boat with a 'moon pool', or hatch from the deck to the water, makes coring much easier. The Rising Tide project in Orkney uses a vibrocorer mounted on a raft, in order to extract sediment cores from sheltered bays and inlets (Fig. 2.6b). In the deep sea, there are many different coring devices which operate from high-tech survey vessels. Obviously, they hold the advantage of being able to work below significant water depths and they are able to penetrate very precisely to a considerable depth within the sediments. On occasion, sediments are not suitable for coring and it becomes necessary to dig a trench, or pit, in order to take samples (Fig. 6.8).

The extracted core is held within a tube, usually of metal but occasionally of plastic. Depending on the analysis these may be wrapped and transported to a lab to be opened and sampled under controlled conditions. If they are to be stored for a while, then refrigerated storage is necessary to ensure that the organic material does

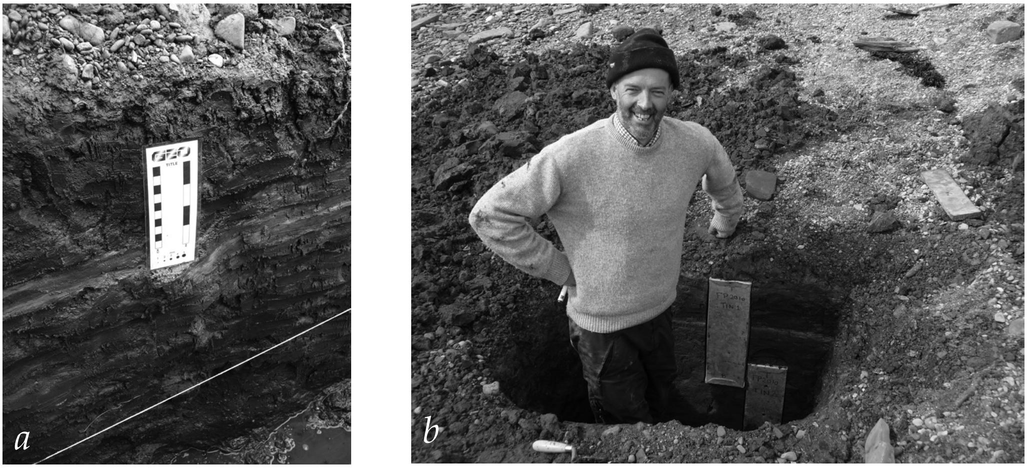


Fig. 6.8 Taking samples for environmental analysis from a pit: a) clear differences in sediment are visible in the sides of the pit; b) using Kubiena tins to extract samples

not deteriorate. In some cases, the core can be cut open and sampled in the field. The remaining half of the core would then be wrapped with cling film and packaged for transport to the lab. It is always useful to preserve unused and duplicate samples for further analysis. Accurate, three-dimensional locations should be recorded for every core, using a D-GPS or other locational device, and careful measurement of the depth of individual samples along the core is vital in order to relate material to the specific landscape or chronological period.

Sediment from one core may preserve a wealth of information relating to the past environment so that a variety of techniques of analysis is likely to be employed. Essentially, the different elements within the sediment provide a snapshot back through time, of the changing conditions around the core site. Many different elements may be preserved within the sediments, including shells, pollen, insect remains, and other microfossils, so it is important to select the samples to analyse and the material that will be investigated with care (Fig. 6.9). In general, only very small quantities of sediment are required so that careful sampling will leave duplicate material for further investigation as new techniques of sediment analysis are developed.

Microfossils

The environmental data preserved within a sediment core includes microfossils such as diatoms, insect remains, ostracods and foraminifera. It also includes plant material such as pollen, or even microscopic charcoal. Most living things prefer very specific conditions and so by analysing the environmental material at different levels within a core it is possible to build a picture of the precise environmental conditions at different periods.

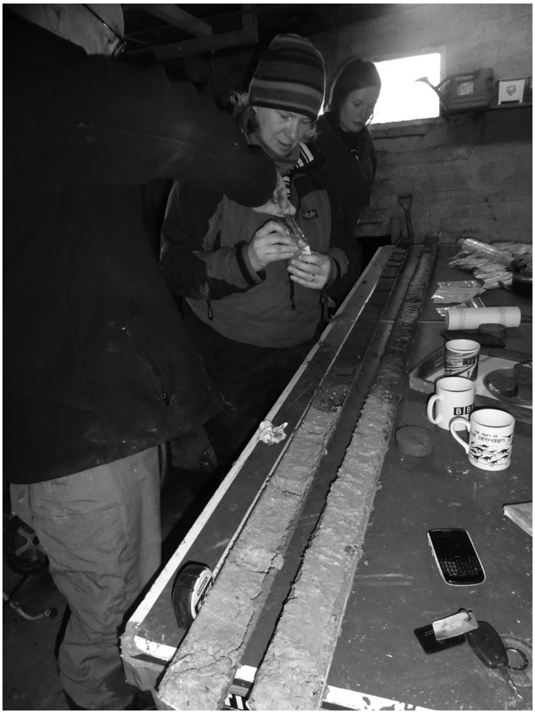


Fig. 6.9 Sampling the core. The difference in the sediment is clearly visible

Diatoms comprise algae with a siliceous skeleton and it is this skeleton that survives (Fig. 6.10). They live in all aquatic environments. Diatoms range in size from 20 μm to 2 mm. Fortunately for us, there are many different diatoms, living in very specific conditions including a precise range of salinity and temperature. Different types of diatoms are identified by their skeletons and they are much used as an indicator species relating to the salinity, or otherwise, of water. They are thus a sensitive indicator relating to changes in sea-level.

Ostracods are a form of aquatic crustacea around 1 mm in size, with calcite carapaces which allow the different species to be distinguished (Fig. 6.11). The different marine and freshwater forms are of particular use for sea-level studies. Foraminifera, however, are mainly marine species; they possess a shell, and provide useful information relating to oceanic conditions such as temperature and depth. Foraminifera that prefer saltmarsh and intertidal flats are of the greatest use for the reconstruction of relative sea-level.

Insect remains comprise a variety of material including chironomids: a family of non-biting midges. Chironomids are very sensitive to temperature, water acidity and nutrients, and the presence of pollutants, so that analysis of specific chironomid types allows us to reconstruct information on these aspects of the past environment.

Other microfossils comprise plant remains such as pollen, phytoliths (silica-rich structures that develop within the tissues of some plants, especially siliceous species such as grasses), or even preserved organic material and microscopic charcoal. The analysis of this type of evidence is a valuable part of unravelling the nature of the palaeoenvironment. Not only does it provide a guide to the plant species that have been thriving in the vicinity of the core site, but it can provide wider information on the landscape as well. Because individual species each have preferred growth conditions, it is possible to build an overall idea of other aspects such as rainfall, winter and summer temperatures, proximity of the sea, even wind conditions.

Information from remains such as these may be cross referenced to build a more rounded picture of the past environment. Investigation of information from different heights within the core may then be combined and dated to record changes in the environment through time, such as the onset of colder or wetter conditions, or inundation by rising relative sea-levels.

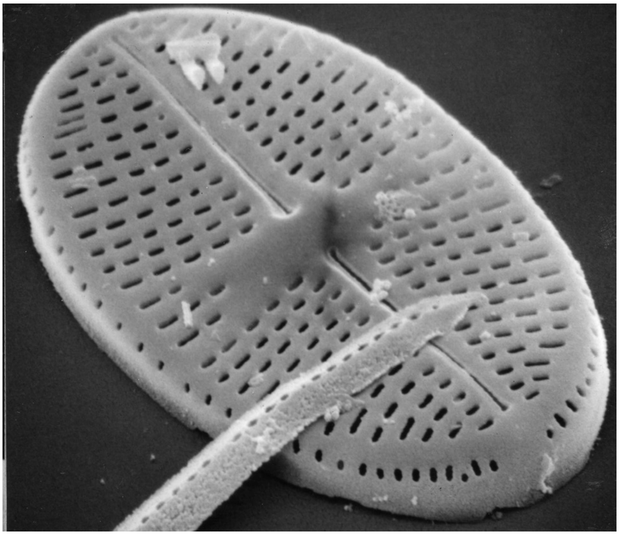


Fig. 6.10 Diatoms. One valve of Psammothidium subatomoides. This diatom is non-planktonic and lives attached to submerged surfaces in relatively shallow, fresh water. The size of the diatom is a bit less than about 10 μm × 4 μm. The valve is composed of silica and is half of a cell wall. Diatoms such as these are found in nutrient poor freshwater sediments by the coast and may be found in the freshwater sections of sea level sequences. Image: Nigel Cameron, University College London

Geochemistry

It is also possible to analyse the geochemical properties of the sediments and use the results, such as the changing amounts of trace elements like calcium, iron and potassium at different heights within the core, to infer changes such as the development of drier or wetter conditions, the presence or absence of marine conditions, the episodic wind deposition of terrestrial sediments, or temperature fluctuations (Rothwell and Croudace 2015). Although the analysis of these properties has been undertaken since the 1930s, in recent years the use of X-ray fluorescence to record the reaction of the different components within the sediments to incident X-rays has facilitated research. Different materials fluoresce separately according to the energy and wavelength properties of the X-ray source, so that by scanning a core segment through a range of variants within the source it is possible to pick out the elements within it.

In the last two decades, the development of improved core scanners, such as the ITRAX scanner, has facilitated the collection of high resolution data (Croudace and Rothwell 2010). One advantage of this type of scanning is that it is non-destructive of the core (Fig. 6.12), thus leaving the sediment samples for repeat or supplementary analyses, though it can be expensive. In addition to information on past environmental and climatic conditions and changes, it is possible to identify specific events such as the ash fallout from volcanic eruptions or even the provenance of particular deposits of sediment by matching the elemental composition of the material with that from cores and sediments elsewhere. The development of smaller and more sophisticated scanning equipment, such as the SCiO Spectrometer opens the possibility for some analysis to be done in the field and will, no doubt, improve the analysis of core data in future.

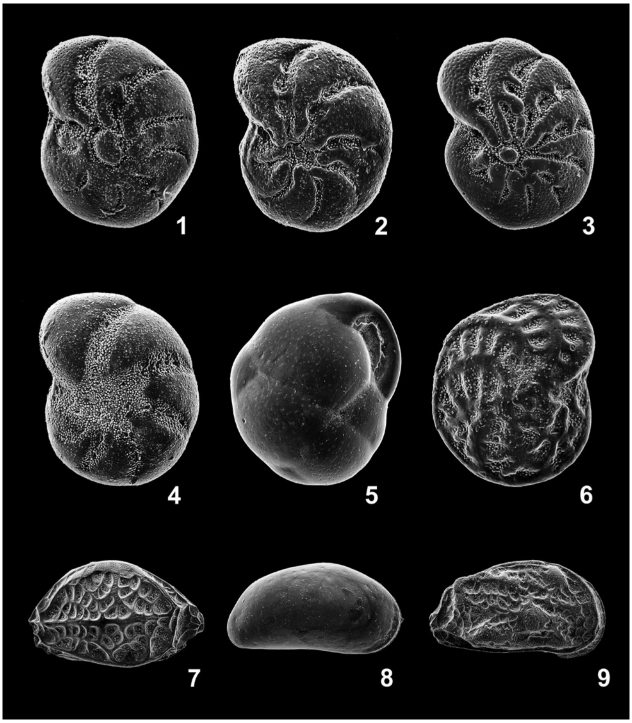


Fig. 6.11 Foraminifera (1–6) and ostracods (7–9) from the interglacial site at Norton Farm, West Sussex (Bates et al. 2000). 1–3: Elphidium clavatum Cushman; 4: Elphidium albiumbilicatum (Weiss): 5: Cassidulina reniformis Nørvang; 6: Elphidium cf. fichtellianum (d'Orbigny); 7: Hemicytherura clathrata (Sars); 8: Sarisicytheridea bradii (Norman): 9: Finmarchinella angulata (Sars). Image: John Whittaker, Natural History Museum

Sedimentary DNA

The survival of ancient DNA (aDNA) in samples of animal material has been discussed and evaluated since the 1980s (Willerslev and Cooper 2005). Initial issues with contamination from modern DNA or microbial and fungal DNA have now been resolved, leaving aDNA as a valuable archaeological technique (e.g. Cucchi *et al.* 2014).

While the application of aDNA for the identification of species is useful, traditionally, it relies on the survival of suitable samples of material such as bone or tooth. This limits the application of the technique in relation to marine sediments, as larger organic elements are rare in a core. Nevertheless, there is a place for aDNA work here and this relates to the existence of aDNA within the sediment itself. Within any location, the plants and animals that have populated the area all leave trace deposits of DNA in the local sediments, and it is now possible to isolate and examine it. The presence and survival of useful aDNA within sediments may seem unlikely, but it has been well studied (Willerslev *et al.* 2003) and is recognised as a valid research tool (Rawlence *et al.* 2014; Smith *et al.* 2015; Birks and Birks 2016). Vince

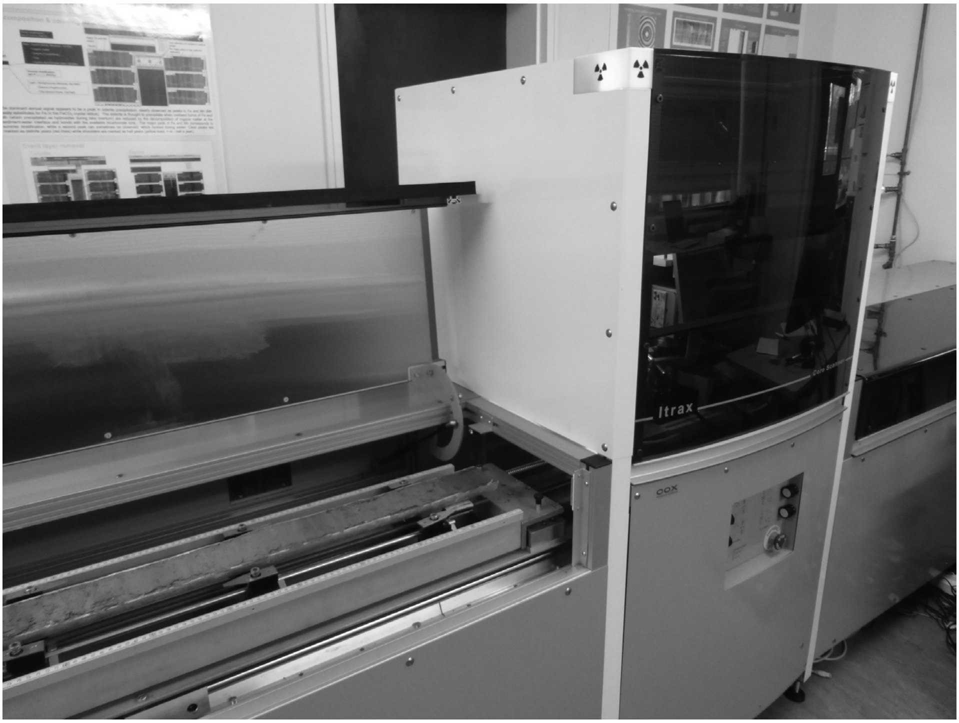


Fig. 6.12 Scanning a core. The core may be seen on the left as it moves through the ITRAX scanner. Image: Sarah Davies, Aberystwyth University

Gaffney and his team are working on the extraction of samples of sediment DNA for their reconstruction of the flora and fauna of Doggerland (Gaffney *et al.* 2017), while others seek human DNA as evidence of early migrations (Flemming 2017b). The technique is still innovative and new publications often reveal necessary refinements, but it is a promising step forward in the reconstruction of the submerged landscape. Work to date suggests that the cool, sealed, conditions of marine sediments provide ideal surroundings for the preservation of aDNA at least since the Late Glacial period and that the surviving aDNA within a sediment can be a reliable indicator of species local to the core site.

Dating

Accurately constrained dating is necessary in order to tie down individual events and build a sequence of landscape and palaeoenvironmental change. The most common method of dating is the use of radiocarbon assay on organic material obtained from a sediment core, adjacent to the specific indicators of environmental change. This provides a date for the change or event, and, where other examples of that change can be dated in other cores, it is possible to build up more accurate information across space. Occasionally it is possible to date pollen or coral growth. Other techniques like Uranium-Thorium dating (Dutton 2015) or Optically Stimulated Luminescence (OSL) dating (Rhodes 2011) are increasingly common.

Individual dates are of limited value for any consideration of submerged landscapes, sites and environments, just as the dating of an archaeological site on land requires the construction of a sequence of dates. Archaeological dating (on land or underwater) is not yet an absolute science that relates to human years but rather a statistical process that calculates the probability that a specific sample relates to a particular period in time. Statistically, it is possible to refine the processing of radiocarbon dates by applying information related to the context and known archaeology, so that a smaller, higher resolution, envelope of probability for the date is obtained. This is known as Bayesian Dating (Bayliss 2009).

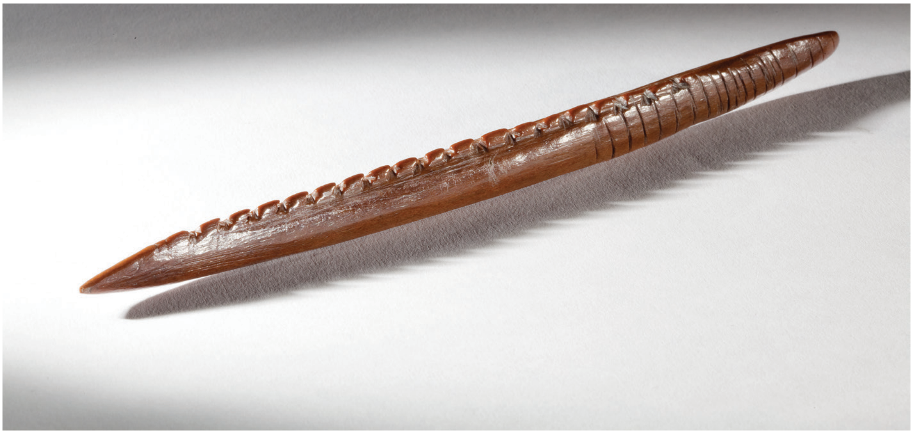


Plate 1. The Colinda Harpoon. Reproduced with permission of the Norwich Castle Museum and Art Gallery

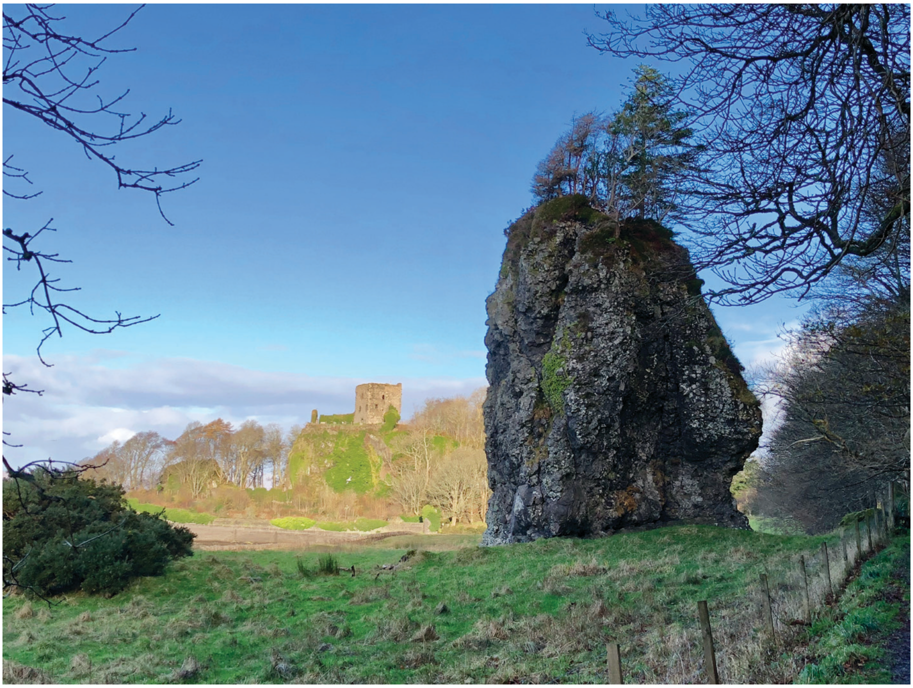


Plate 2. The Dog Stone, Oban, is a good example of an ancient sea-stack sitting on the Main Postglacial Shoreline. It has been left well above the present shore, due to the fall in relative sea-level since the end of the last ice age. Holocene gravels have been recorded on top of the postglacial shore here, so that the coastline to which the Dog Stone relates must be earlier. Image: Sue Dawson, University of Dundee

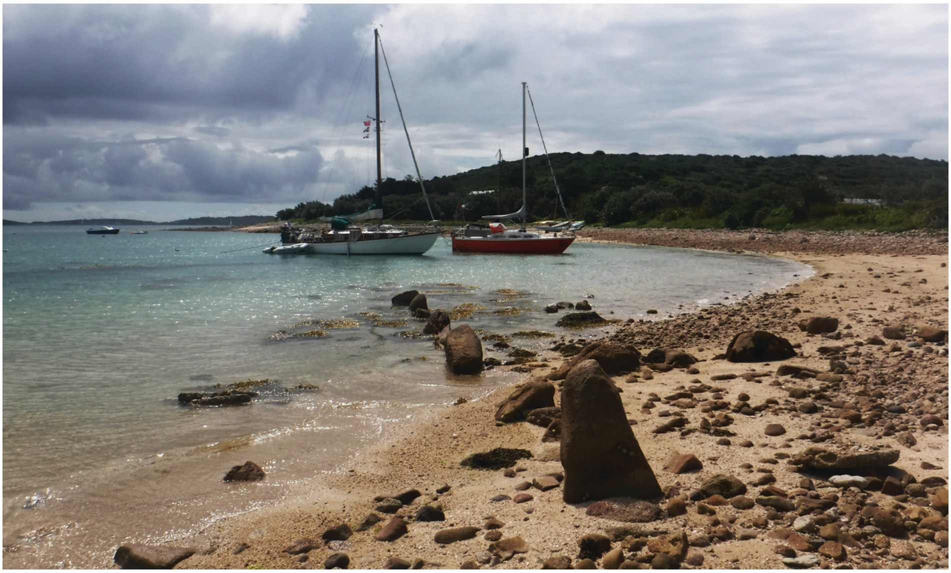


Plate 3. The shallow waters of the Isles of Scilly give an idea of the wealth of archaeology preserved on the submerged landscape. In Green Bay, Bryher, the stones from a prehistoric field system now run into the intertidal zone. Image: Charlie Johns, © Cornwall Archaeological Unit

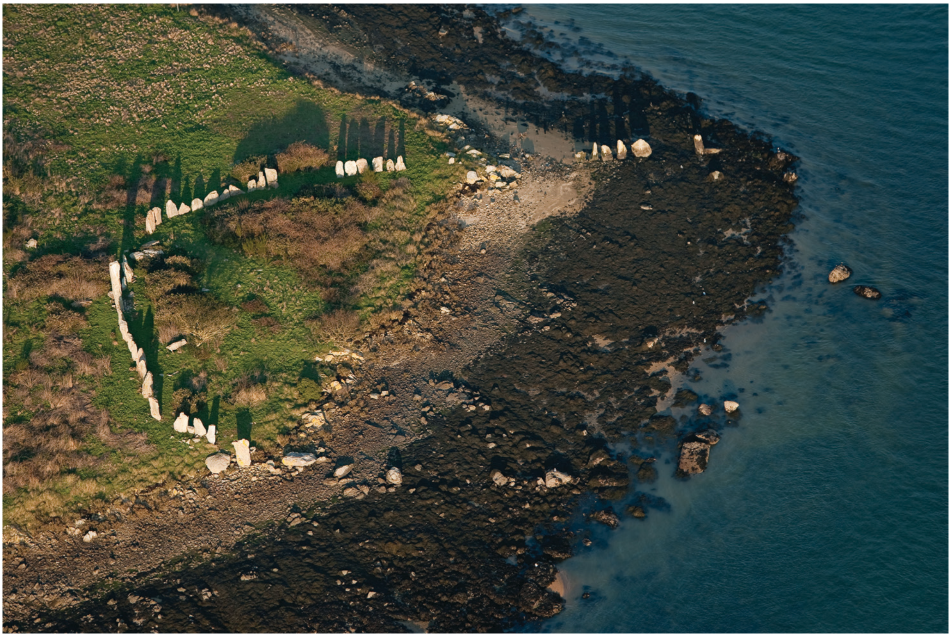


Plate 4. The stone setting of the island of Er Lannic in the Morbihan, France, provides a good example of the impact of rising relative sea-levels on archaeology. The stones of the circle may be seen to disappear into the intertidal zone and indeed a second setting has been recorded underwater. Image: Emmanuel Berthier, Hemis, Alamy Stock Photo

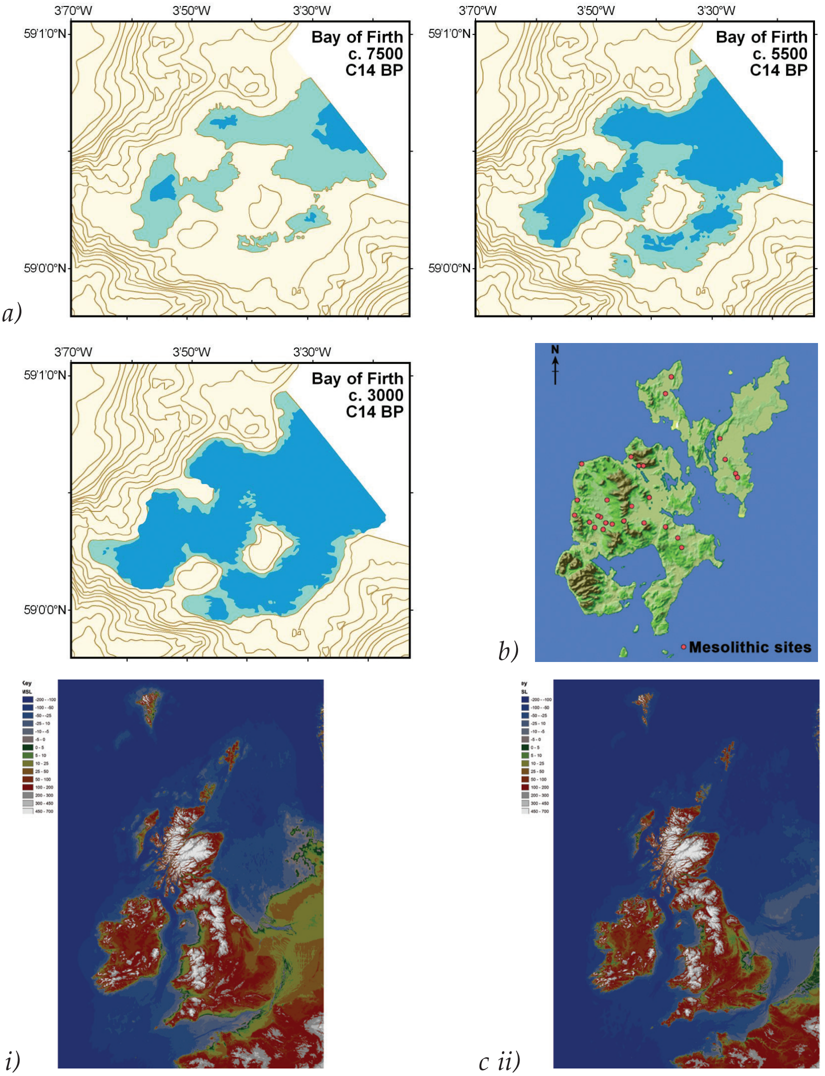

3'70°W
3'50°W
3'30°W
59'1'0°N
59'0'0°N
Bay of Firth c. 7500 C14 BP
Bay of Firth c. 5500 C14 BP
Bay of Firth c. 3000 C14 BP
a)
N
Mesolithic sites
b)
Key
c i)
c ii)

Plate 5. These images look like maps, but they are models, based on the combination of a variety of data. The modelling of relative sea-level change can take place at many different scales and it is important to select the scale appropriate to the questions you are asking.

a) Models of marine transgression in the Bay of Firth, Orkney at key points for the human settlement of the area, based on numerous data points drawn from within the bay. Image: Richard Bates, University of St Andrews and Rising Tide.

b) Model of relative sea-level around Orkney c. *8000 years ago. Data from wider spaced SLIPs has been combined with other relevant information on past coastal features to produce a more generalised model that still gives a good idea of the way in which the archipelago has changed since then.*

c) Models of the development of the North Sea at two key times (i: 11,000 BP; ii: 6000 BP), based on data from SLIPs combined with modelling of deglaciation and crustal rebound. Models such as this give a good idea of broadscale change; while they provide a good indication of areas for further investigation, they cannot be used to discuss the behaviour of individual human communities. Images: Fraser Sturt, University of Southampton

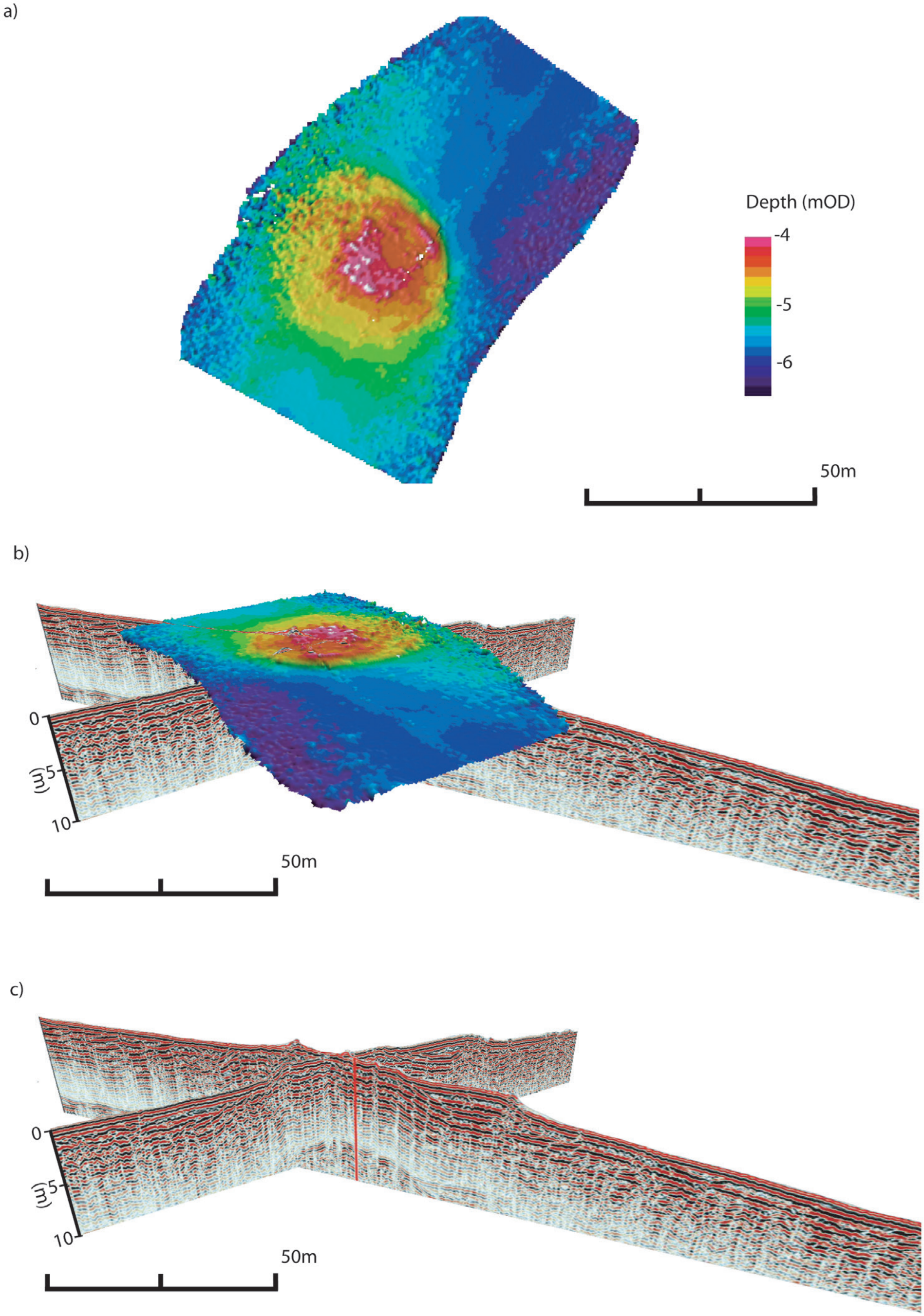


Plate 6. The Bay of Firth, Orkney: a combination of sonar survey with seismic survey to examine a seabed feature. Image: Richard Bates, University of St Andrews

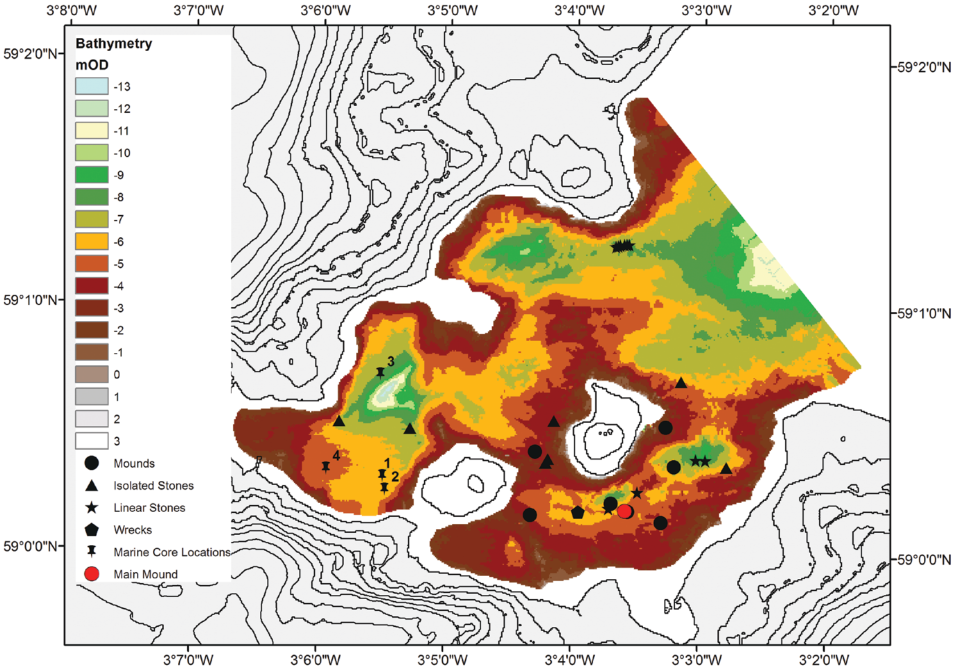

3°8'0"W
3°7'0"W
3°6'0"W
3°5'0"W
3°4'0"W
3°3'0"W
3°2'0"W
59°2'0"N
59°1'0"N
59°0'0"N
Bathymetry
mOD
-13
-12
-11
-10
-9
-8
-7
-6
-5
-4
-3
-2
-1
0
1
2
3
Mounds
Isolated Stones
Linear Stones
Wrecks
Marine Core Locations
Main Mound
1
2
3
4

Plate 7. The Bay of Firth, Orkney: survey features. Image: Richard Bates, University of St Andrews

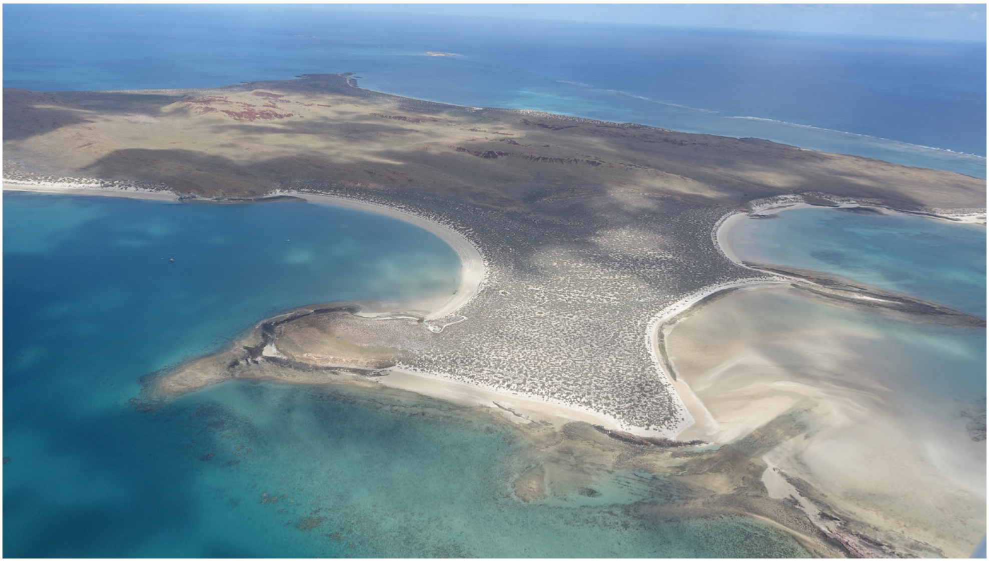


Plate 8. The Dampier Islands, Northwestern Australia: Rosemary Island from the east at low tide (25 September 2017). This aerial photo gives a good idea of the location as well as the shallow seas between the islands. Image: Shakti Chakravarty/Airborne Research Australia

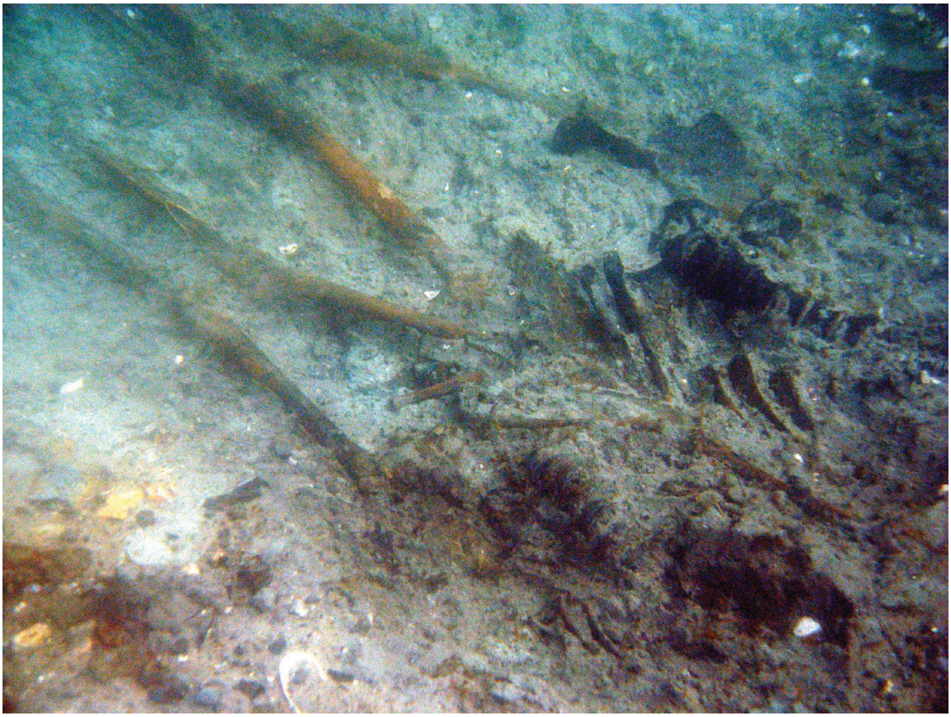


Plate 9. Tybrind Vig, Denmark: Mesolithic double burial on the seabed, shortly after discovery. Image: Langelands Museum

Plate 10. Tybrind Vig: an archaeological diver working with an ejector pump. Image: H. Dal. Moesgaard Museum, National Museum of Denmark, Jutland Archaeological Society, courtesy Søren Andersen

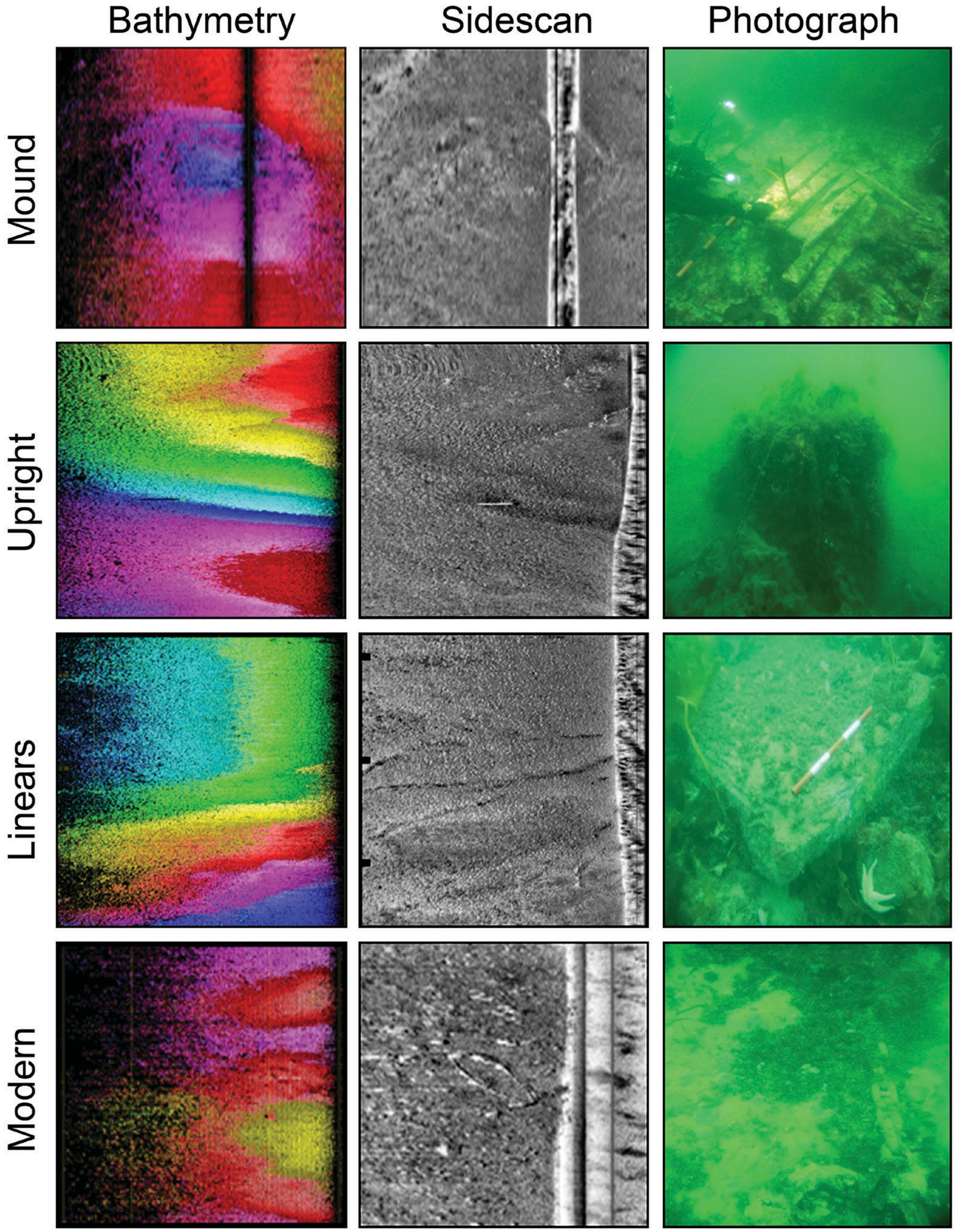

Bathymetry
Sidescan
Photograph
Mound
Upright
Linears
Modern

Plate 11. Orkney, a range of stone features recorded by multibeam, sidescan sonar, and photography. None has yet been definitively authenticated as anthropogenic. Image: Richard Bates, University of St Andrews

Plate 12. Orkney: recording intertidal features. Image: Martin Bates, University of Wales, Trinity St David

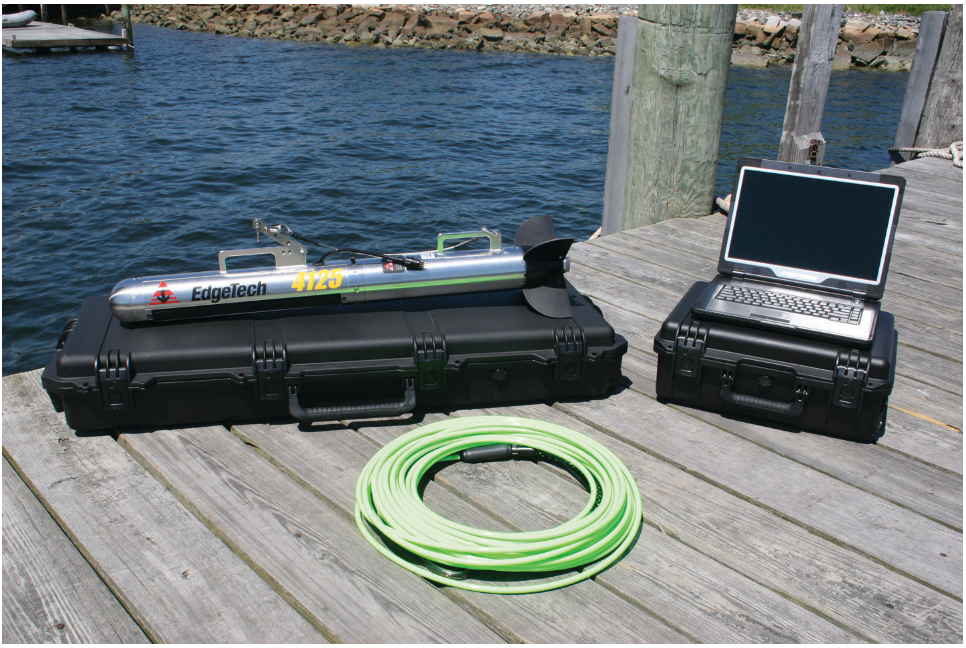


Plate 13. EdgeTech sidescan sonar system: the 4125 is designed to be towed and used for shallow water operations. Image: EdgeTech

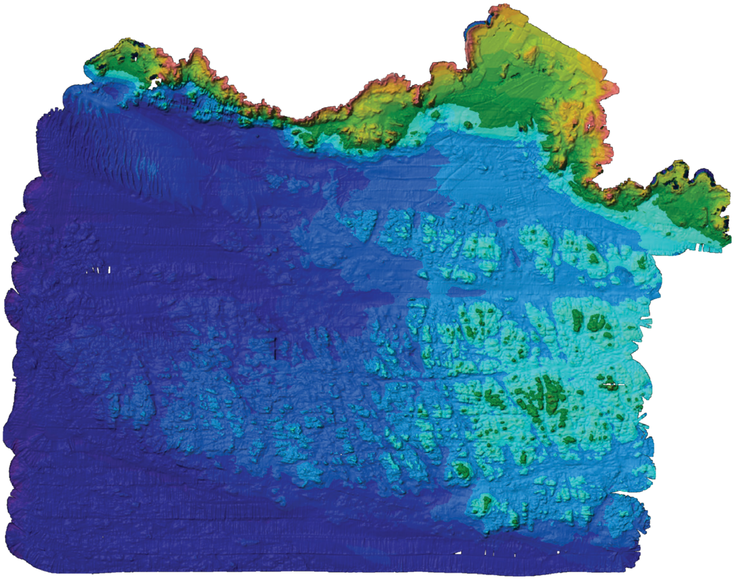


Plate 14. Multibeam survey results in a three-dimensional image of the seabed as seen here offshore from the south coast of Jersey. Image: Richard Bates, University of St Andrews

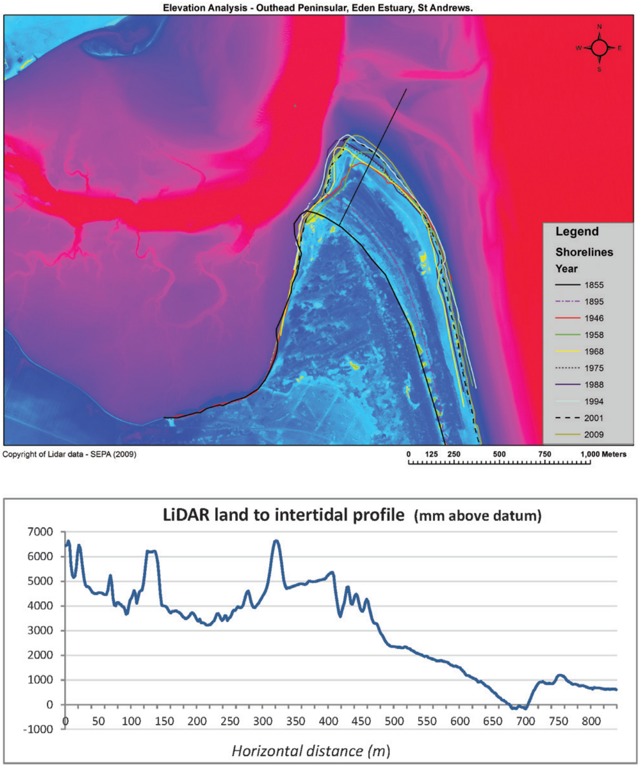

Elevation Analysis - Outhead Peninsular, Eden Estuary, St Andrews.
N
W
E
S
Legend
Shorelines
Year
1855
1895
1946
1958
1968
1975
1988
1994
2001
2009
Copyright of Lidar data - SEPA (2009)
0
125
250
500
750
1,000 Meters
LiDAR land to intertidal profile (mm above datum)
7000
6000
5000
4000
3000
2000
1000
0
-1000
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
Horizontal distance (m)

Plate 15. In the estuary of the River Eden, Fife, LiDAR survey data has been used to analyse the seawards advance of new dune growth across the land and out into the intertidal zone. The profile shows the elevation along the cross section marked in black. Image: Melanie Chocholek, University of St Andrews

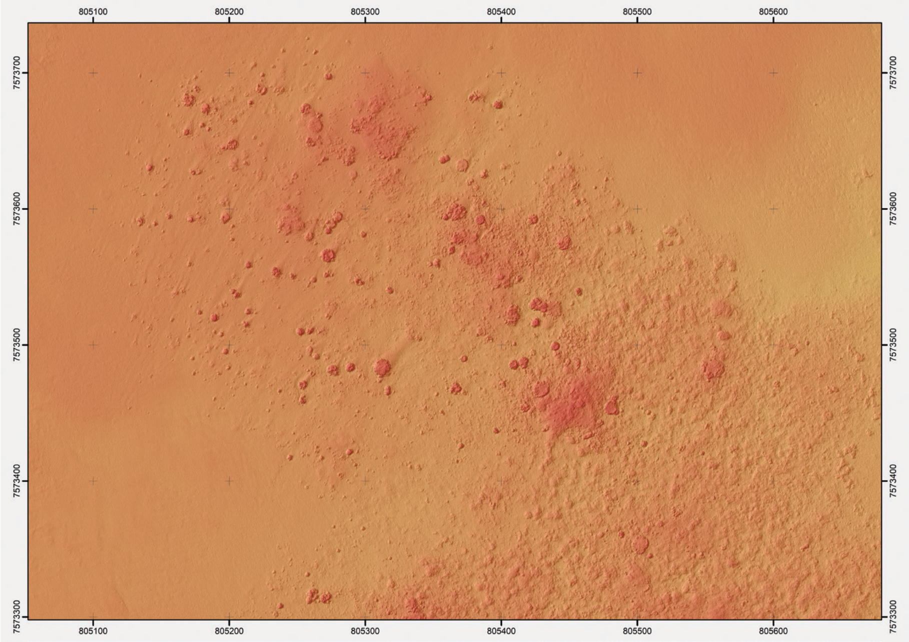

805100
805200
805300
805400
805500
805600
7573700
7573600
7573500
7573400
7573300

Plate 16. High resolution bathymetric LiDAR map of a coral bommie garden on the Tantabiddi section of the Ningaloo Reef, Australia, depth up to 4 m. The data was collected by Airbourne Research Australia using both full waveform terrestrial scanning RIEGL Q680i-S LiDAR and bathymetric scanning RIEGL VQ-820-G LiDAR in order to map both the sea surface and the seabed. Image: Jorg Hacker, Airbourne Research Australia and Mick O'Leary, Curtin University.

Plate 17. Divers undertaking investigation and coring of the seabed. Image: Richard Bates, University of St Andrews

Plate 18. Tybrind Vig, excavation of a 1 m × 1 m trench. Image: H. Dal. Moesgaard Museum, National Museum of Denmark, Jutland Archaeological Society, courtesy Søren Andersen

Plate 19. Bouldnor Cliff, positioning the grid frame over the site. Image: Roland Brookes, Maritime Archaeology Trust

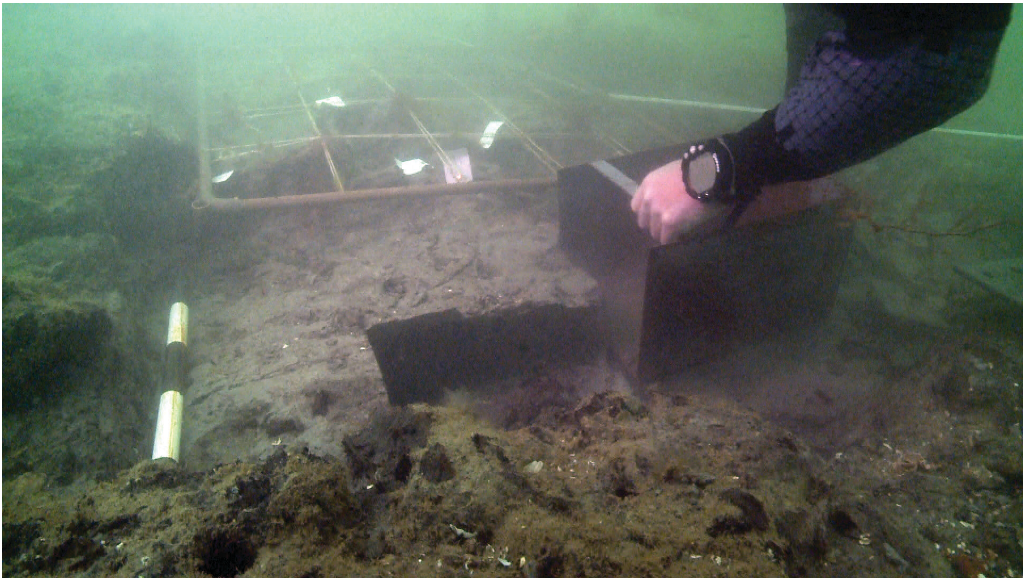


Plate 20. Bouldnor Cliff, sampling the archaeological deposits. Image: Michael Pitts, Maritime Archaeology Trust

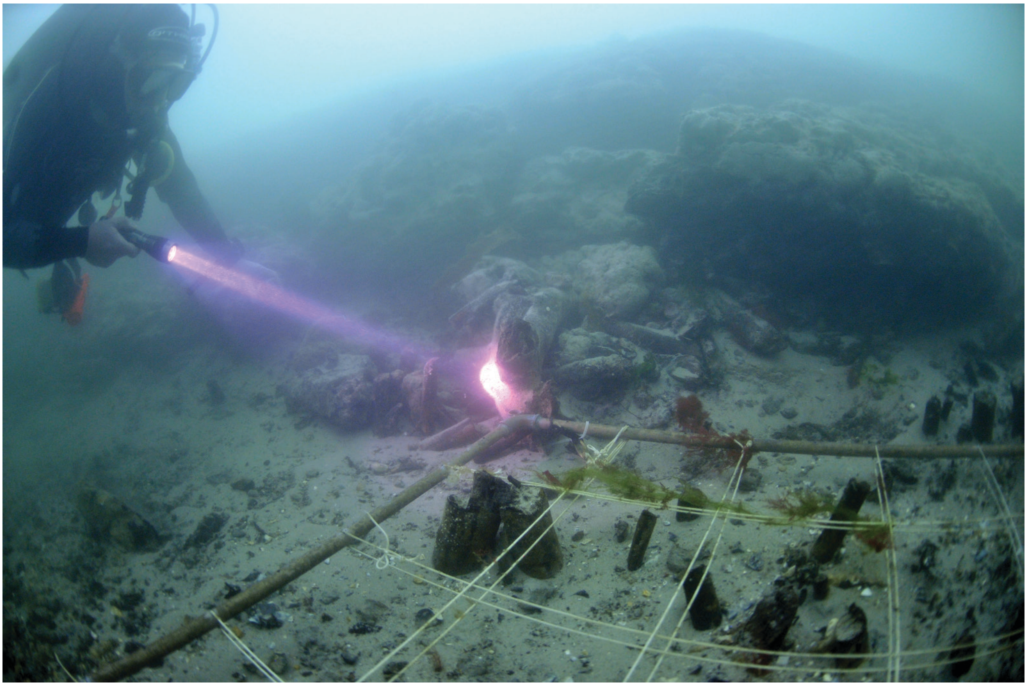


Plate 21. Bouldnor Cliff, inspecting an area of exposed seabed. Image: Roland Brookes, Maritime Archaeology Trust.

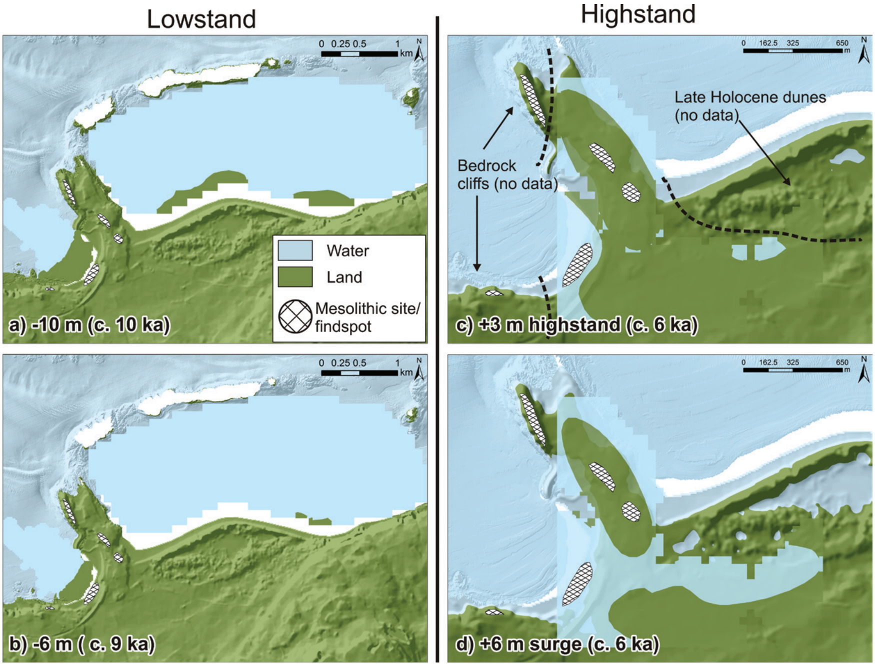

Lowstand
Highstand
0 0.25 0.5 1 km
N
0 162.5 325 650 m
Late Holocene dunes (no data)
Bedrock cliffs (no data)
Water
Land
Mesolithic site/ findspot
a) -10 m (c. 10 ka)
b) -6 m (c. 9 ka)
c) +3 m highstand (c. 6 ka)
d) +6 m surge (c. 6 ka)

Plate 22. Ramore Head, digital terrain models of the landscape at various time slices to indicate the changing relative sea-level and interpret archaeological potential. Image: Kieran Westley, Ulster University

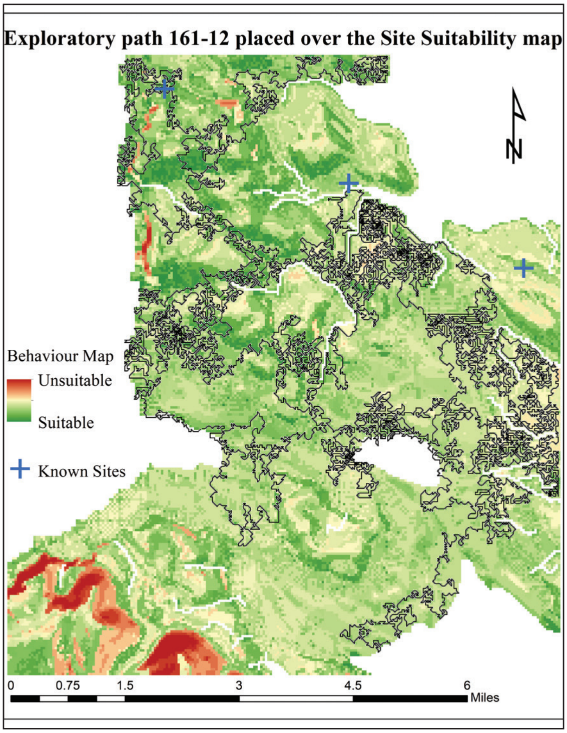

Exploratory path 161-12 placed over the Site Suitability map
N
Behaviour Map
Unsuitable
Suitable
Known Sites
0 0.75 1.5 3 4.5 6
Miles

Plate 23. Agent-based modelling examines likely human behaviour over time within a given set of constraints such as terrain and resources. It can be used to suggest the activities of communities on the submerged landscape. This figure illustrates one of many possible exploration paths within a given terrain. The suitability of the terrain is calculated according to a variety of factors including slope, vegetation, etc. Image: Leo Sucharyna Thomas

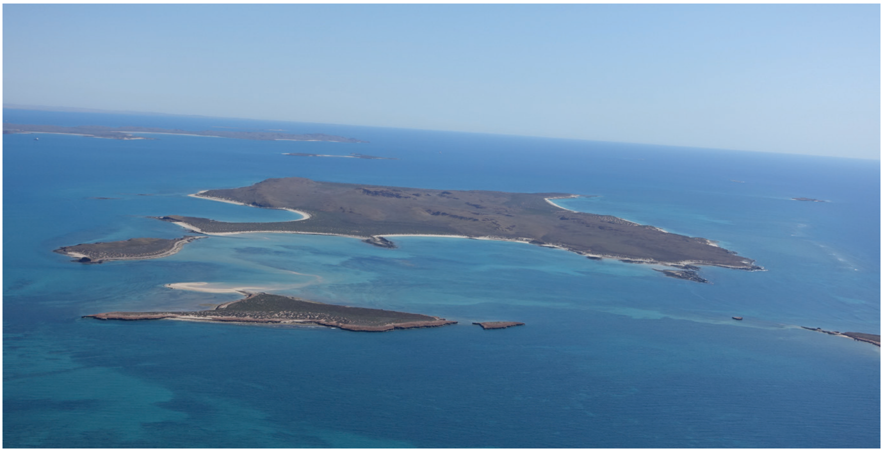


Plate 24. *Dampier Islands, Northwest Australia: Rosemary Island seen from the northeast with Lady Nora Island in the foreground and Goodwin and Enderby Islands in the background. This photo, taken at high tide on 1 October 2017, highlights the possibilities of aerial photography over clear waters in shallow seas. Image: Shakti Chakravarty/Airborne Research Australia*

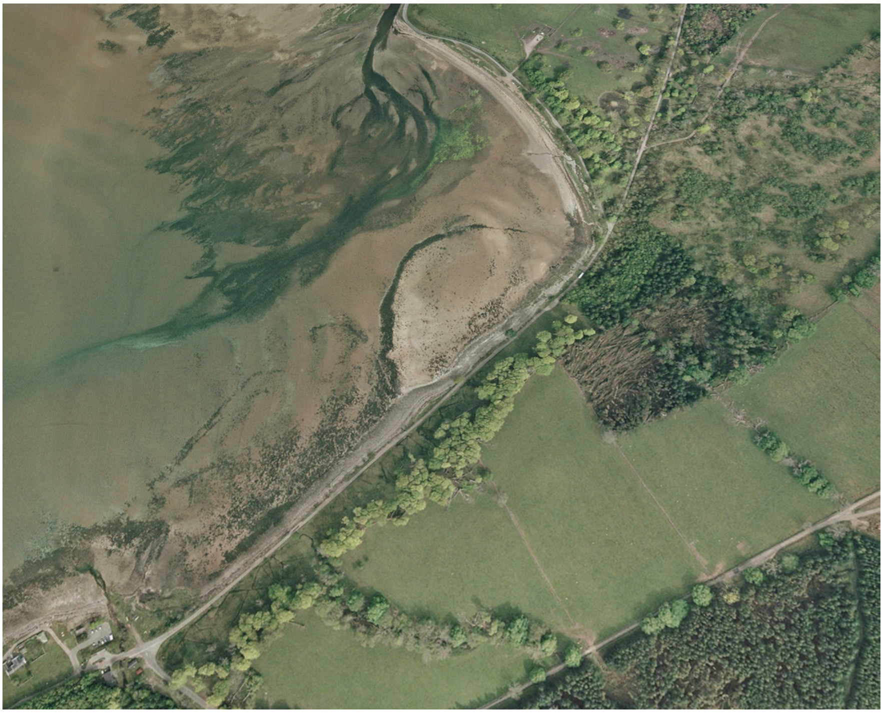


Plate 25. The clarity of Google Earth shows up the semi-circular fish trap in Applecross Bay as well as possible less well-preserved rectilinear structures alongside it. Image Google Earth, © 2018 Getmapping plc

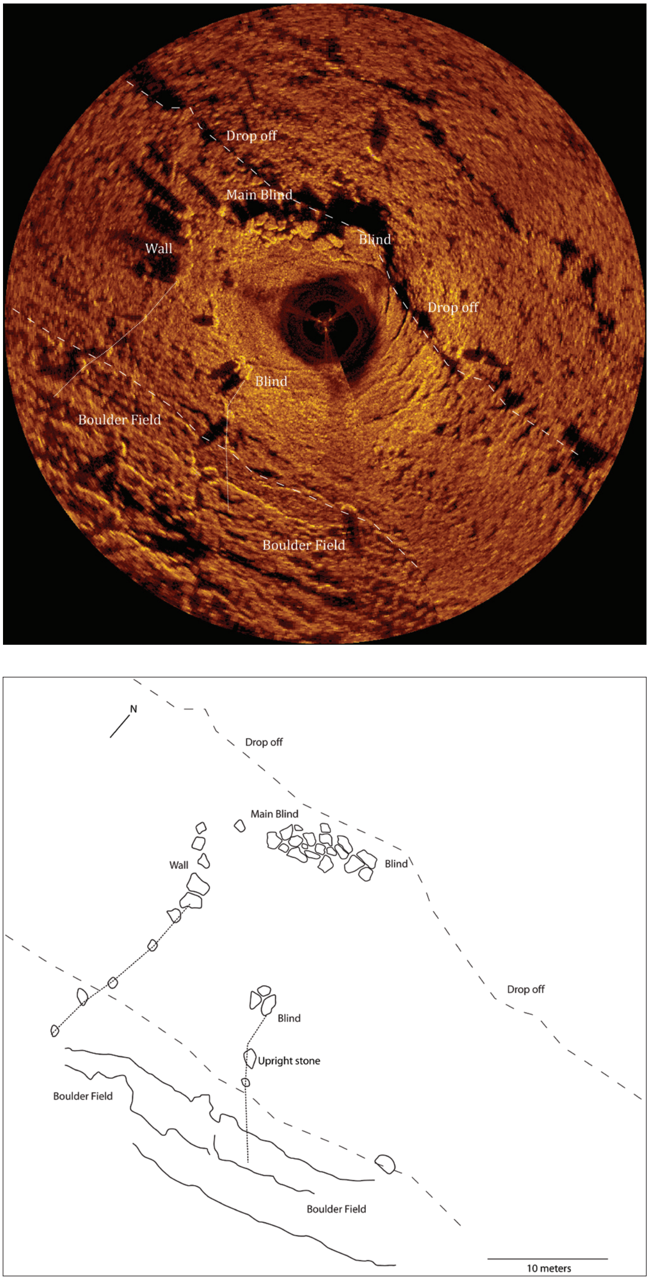

Drop off
Main Blind
Blind
Wall
Drop off
Blind
Boulder Field
Boulder Field
N
Drop off
Main Blind
Wall
Blind
Drop off
Blind
Upright stone
Boulder Field
Boulder Field
10 meters

Plate 26. Research on the floor of Lake Huron, in water depths of over 30 m, has uncovered traces of a prehistoric hunting landscape dating to about 9000 years ago.
a) an acoustic image of the remains which mainly comprise stones and boulders.
b) Diagrammatic interpretation of the hunting trap in a). Images: John O'Shea, Museum of Anthropological Archaeology, University of Michigan

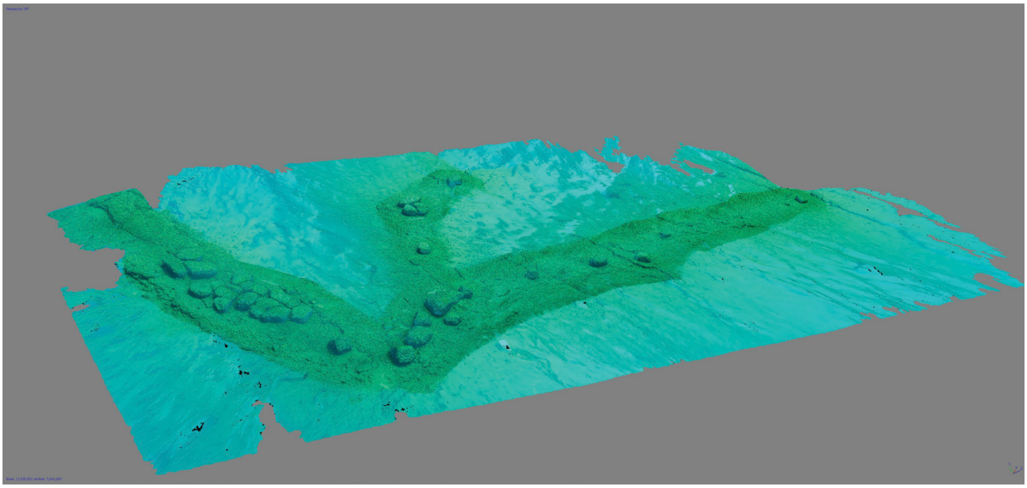


Plate 27. A closer image of the hunting trap in Plate 26. Image: John O'Shea, Museum of Anthropological Archaeology, University of Michigan

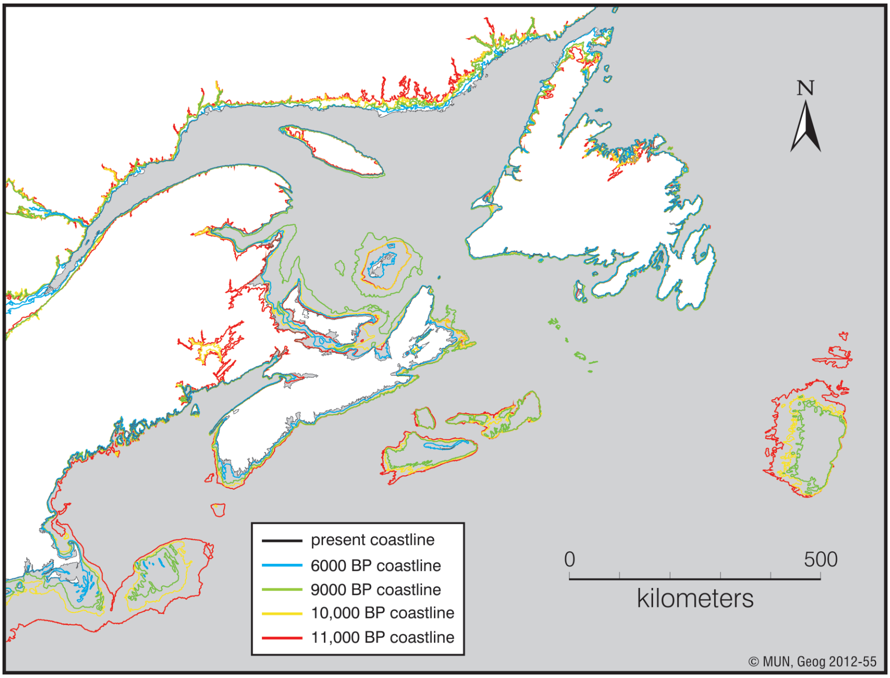

N
present coastline
6000 BP coastline
9000 BP coastline
10,000 BP coastline
11,000 BP coastline
0
500
kilometers
© MUN, Geog 2012-55

Plate 28. The reconstructed coastlines of Atlantic Canada at various periods illustrate the complex evolution of the landscape here. Submergence in the south contrasts with the emergence of the land along the northern coasts. Image: Dominic Lacroix, from Lacroix et al. *2014*

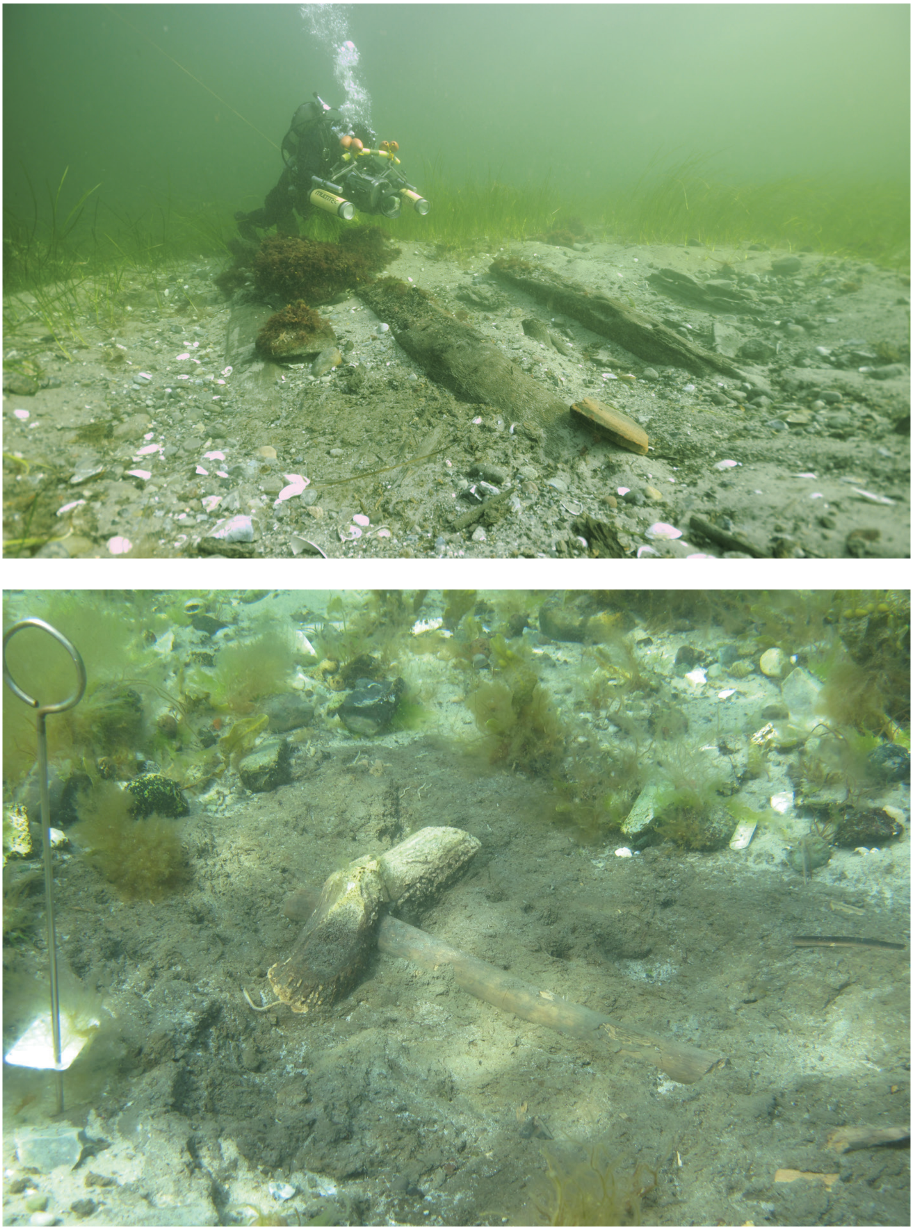


Plate 29. Seabed archaeology varies in scale.

a) The emerging timbers of four trees at Strande LA 163, Kiel Bay, Germany. Image: Gerald Lorenz.

b) An antler axe with its wooden haft still in place at Harnø Sund, Denmark. Image: Peter M. Astrup, from Skriver et al. *(2017)*

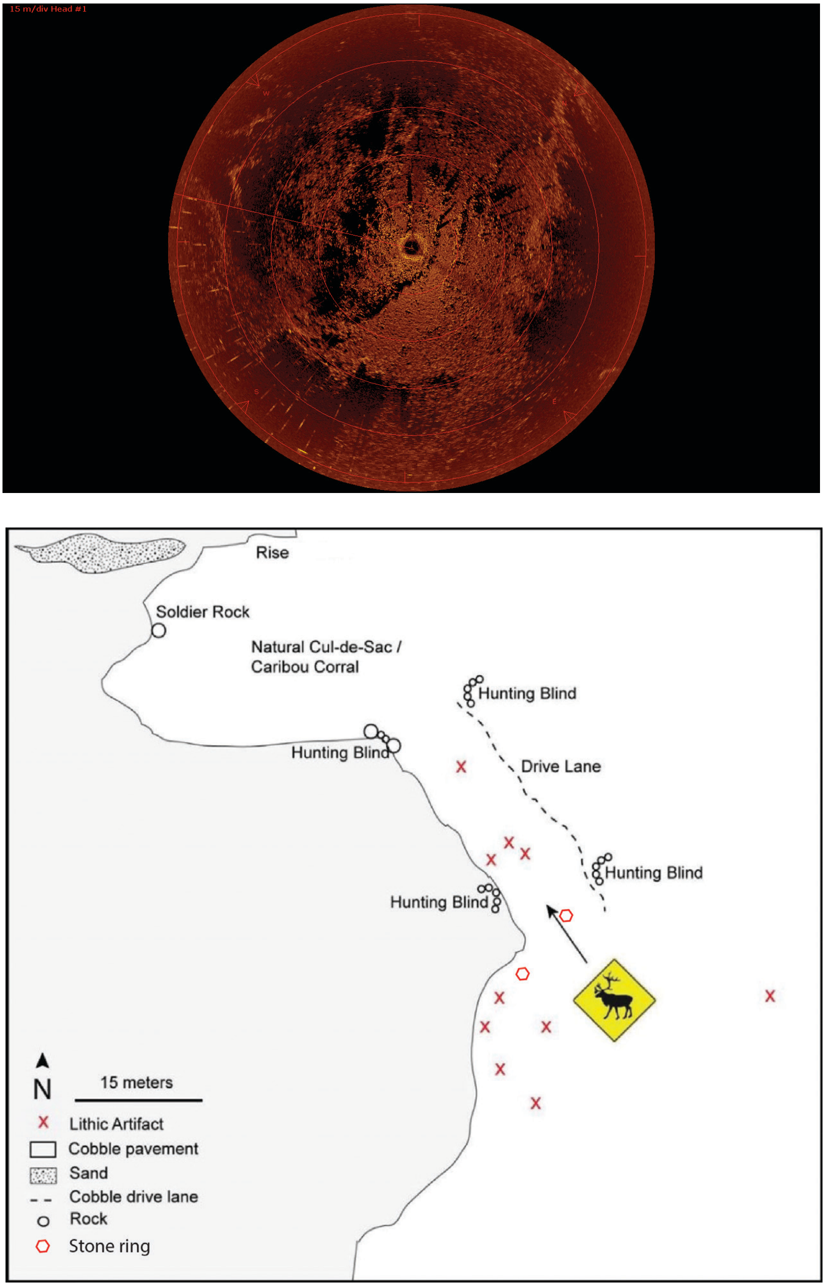
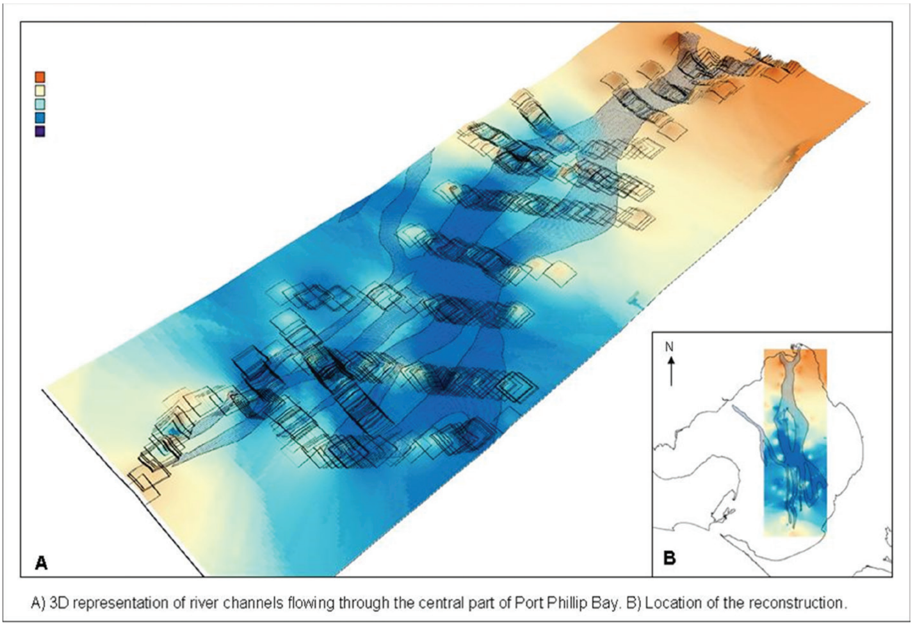

15 m/div Head #1
Rise
Soldier Rock
Natural Cul-de-Sac /
Caribou Corral
Hunting Blind
Hunting Blind
Drive Lane
Hunting Blind
Hunting Blind
N
15 meters
X Lithic Artifact
Cobble pavement
Sand
Cobble drive lane
Rock
Stone ring

Plate 30. Lake Huron: The Drop 45 hunting trap remains

a) An acoustic image produced from a mosaic of scanning images. The location of the scanning unit is the black circle at the centre and the red circles increase in 15 m increments.

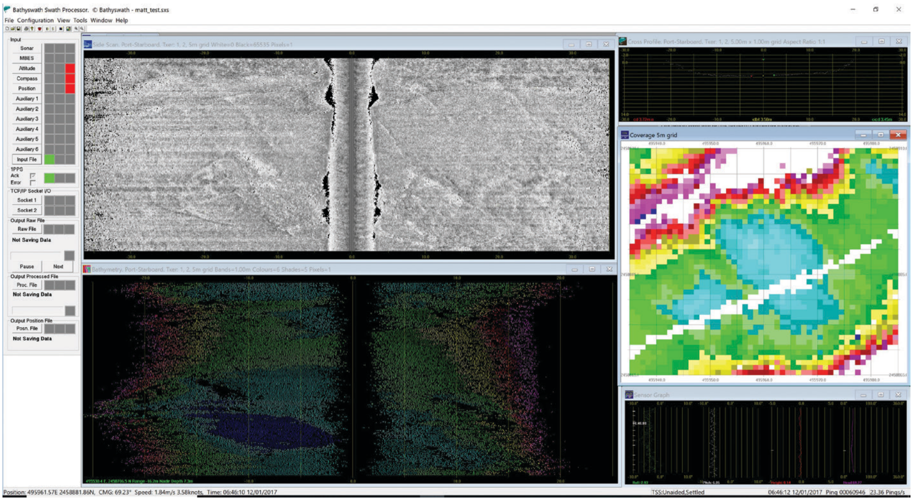
b) Interpretive plan of the scan showing the locations from which artefacts have been collected. Images: John O'Shea, Museum of Anthropological Archaeology, University of Michigan



A) 3D representation of river channels flowing through the central part of Port Phillip Bay. B) Location of the reconstruction.

Plate 31. Port Phillip Bay, Victoria, Australia, the palaeoriver channels that once flowed through the central part of the bay. Image: Hanna Steyne, Heritage Victoria

Plate 32. Archaeological survey in a submerged rockshelter, South West Arm, Port Hacking, South West Australia. Image: David Nutley, Adjunct Research Fellow, Flinders University

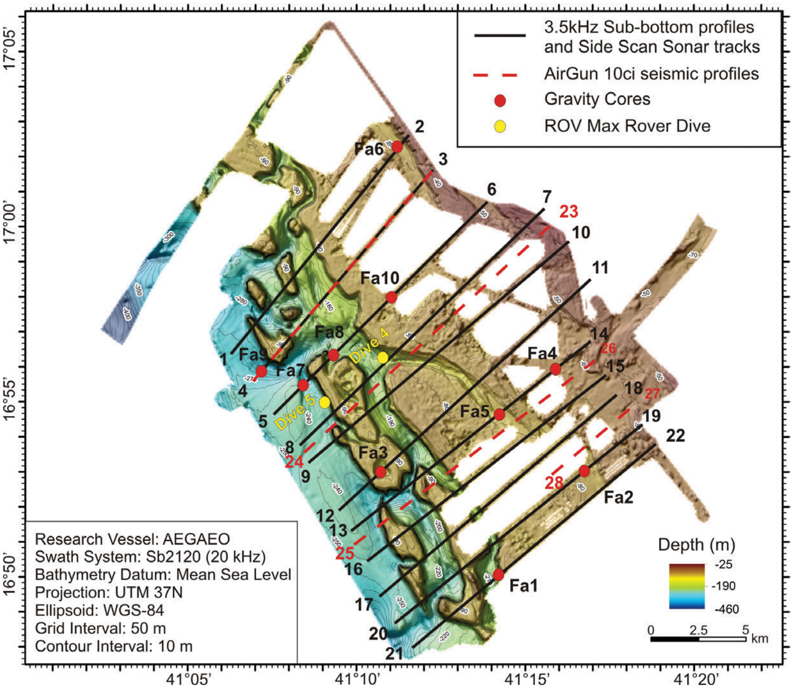

Bathyswath Swath Processor. © Bathyswath - matt_test.sxs
File Configuration View Tools Window Help
Input
Sonar
MBES
Attitude
Compass
Position
Auxiliary 1
Auxiliary 2
Auxiliary 3
Auxiliary 4
Auxiliary 5
Auxiliary 6
Input File
1PPS
Ack
Error
TCP/IP Socket I/O
Socket 1
Socket 2
Output Raw File
Raw File
Not Saving Data
Pause
Next
Output Processed File
Proc. File
Not Saving Data
Output Position File
Posn. File
Not Saving Data
Side Scan. Port-Starboard. Txer: 1, 2, 5m grid White=0 Black=65535 Pixels=1
Coverage 5m grid
Sensor Graph

Position: 495961.57E 2458881.86N, CMG: 69.23° Speed: 1.84m/s 3.58knots, Time: 06:46:10 12/01/2017

TSS:Unaided,Settled

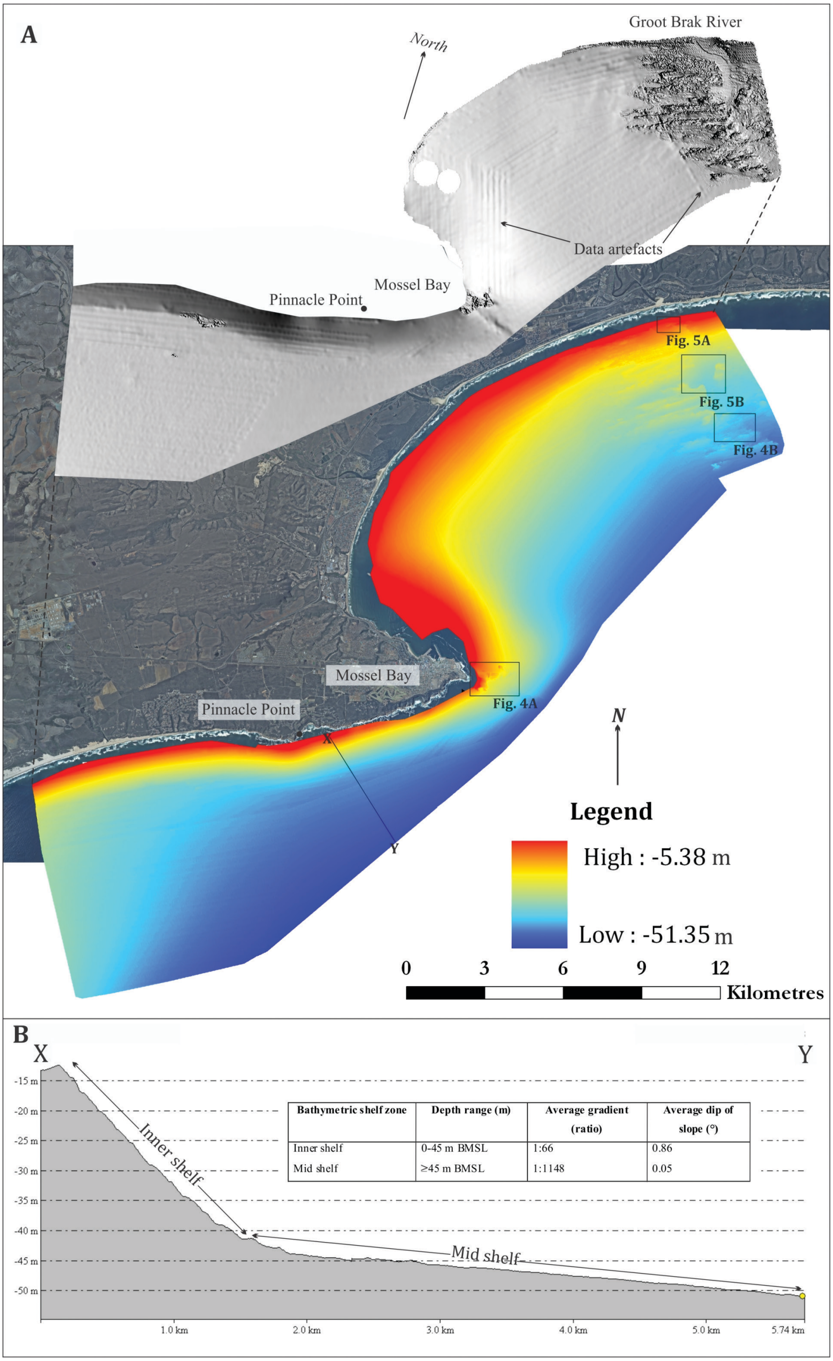
06:46:12 12/01/2017 Ping 00060946 23.36 Pings/s

Plate 33. *Screenshot from sidescan survey using a 468 kHz SwathPlus Bathymetric Sonar at Dwarka, India. The linear features representing walling can be seen. Image: Richard Bates, University of St Andrews*


3.5kHz Sub-bottom profiles and Side Scan Sonar tracks
AirGun 10ci seismic profiles
Gravity Cores
ROV Max Rover Dive
17°05'
17°00'
16°55'
16°50'
41°05'
41°10'
41°15'
41°20'
Fa6
Fa10
Fa8
Fa9
Fa7
Fa3
Fa4
Fa5
Fa2
Fa1
Dive 4
Dive 5
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
Depth (m)
-25
-190
-460
0
2.5
5
km

Research Vessel: AEGAEO
Swath System: Sb2120 (20 kHz)
Bathymetry Datum: Mean Sea Level
Projection: UTM 37N
Ellipsoid: WGS-84
Grid Interval: 50 m
Contour Interval: 10 m

Plate 34. Research in the area of the Farasan Islands in the Red Sea has incorporated a variety of techniques including acoustic survey, seismic profiles and coring. Courtesy of G. Bailey and D. Sakellariou, from Bailey et al. *(2015)*


A
North
Groot Brak River
Data artefacts
Mossel Bay
Pinnacle Point
Fig. 5A
Fig. 5B
Fig. 4B
Mossel Bay
Pinnacle Point
Fig. 4A
X
Y
N
Legend
High : -5.38 m
Low : -51.35 m
0
3
6
9
12
Kilometres
B
X
Y
-15 m
-20 m
-25 m
-30 m
-35 m
-40 m
-45 m
-50 m
Inner shelf
Mid shelf
1.0 km
2.0 km
3.0 km
4.0 km
5.0 km
5.74 km

Bathymetric shelf zone	Depth range (m)	Average gradient (ratio)	Average dip of slope (°)
Inner shelf	0-45 m BMSL	1:66	0.86
Mid shelf	≥45 m BMSL	1:1148	0.05

Plate 35. Mossel Bay, South Africa: location and survey work. Courtesy of Hayley Cawthra, Council for Geoscience, South Africa, from Cawthra et al. *(2011)*

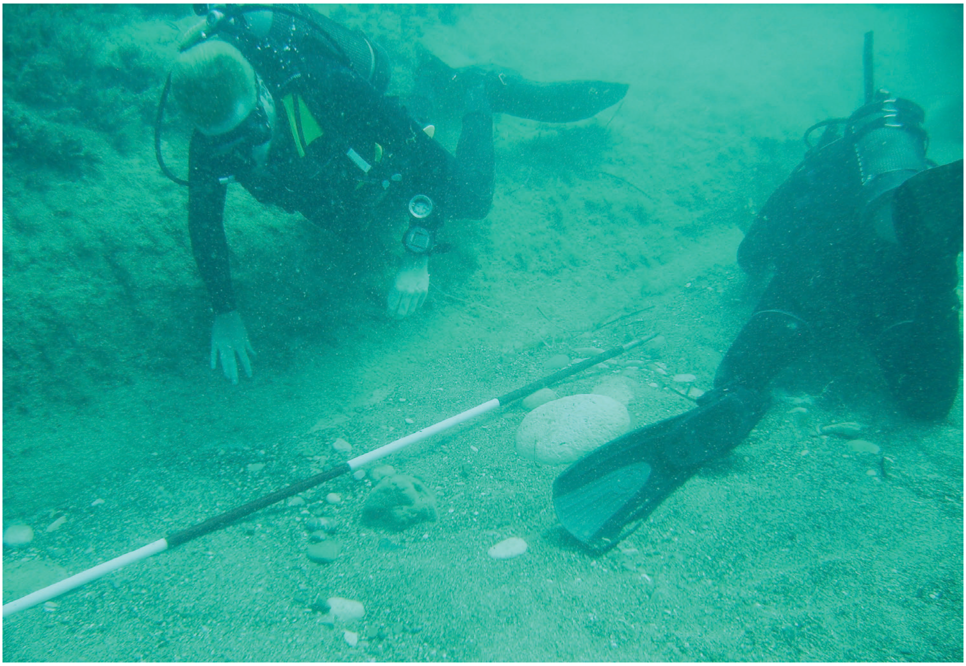


Plate 36. Work in progress at Dive Site C, Cyprus: note the base of the cliff on the left of the diver on the left side of the photograph. Image: A. J. Ammerman, from Ammerman et al. *(2011)*

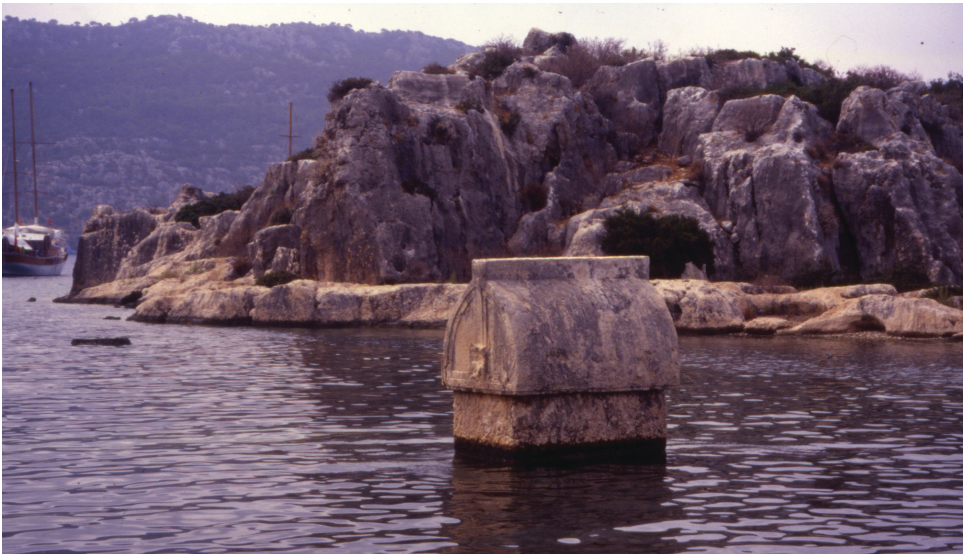


Plate 37. A partially submerged Lycian sarcophagus at Kekova, the site of ancient Simena, southeast Turkey. Image: Özdoğann archive

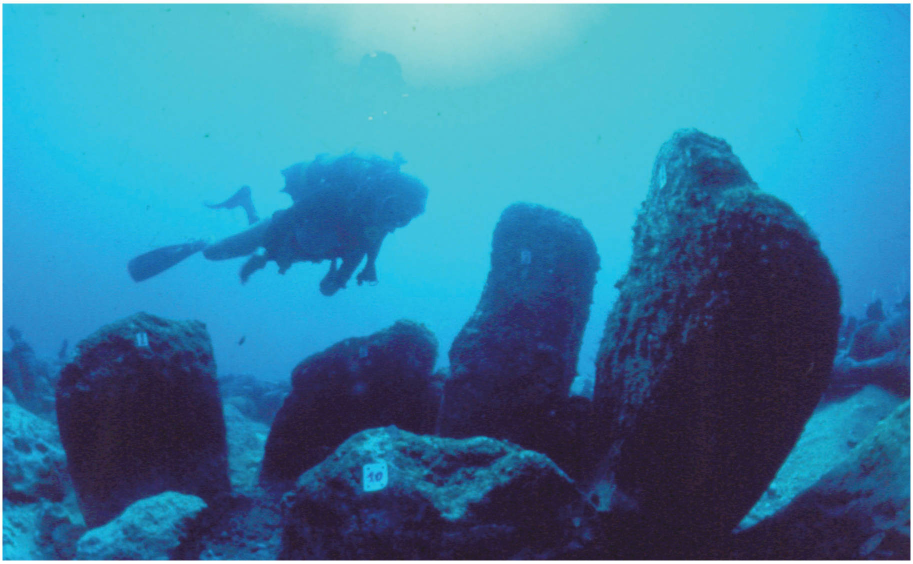


Plate 38. Atlit Yam, Israel, Megalithic structure. Image: Itamar Greenberg, courtesy Ehud Galili, excavator

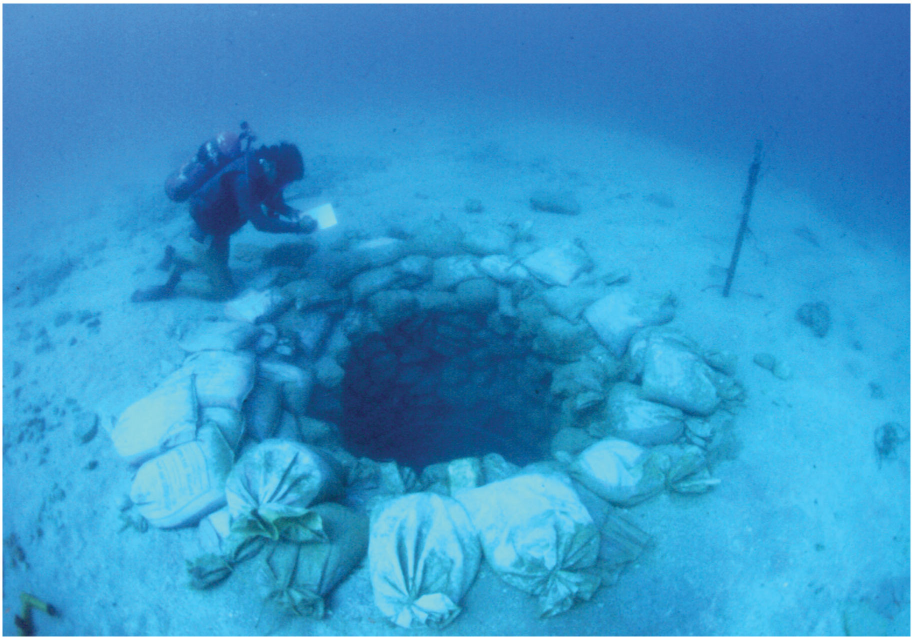


Plate 39. Atlit Yam, Israel, well 11. Image: Itamar Greenberg, courtesy Ehud Galili, excavator

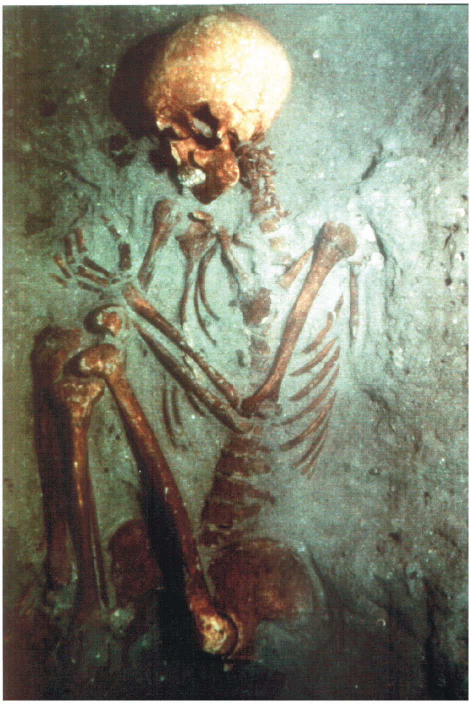


Plate 40. Atlit Yam, Israel, Skeleton H 1, Image: Ahuva Zaid, courtesy Ehud Galili, excavator

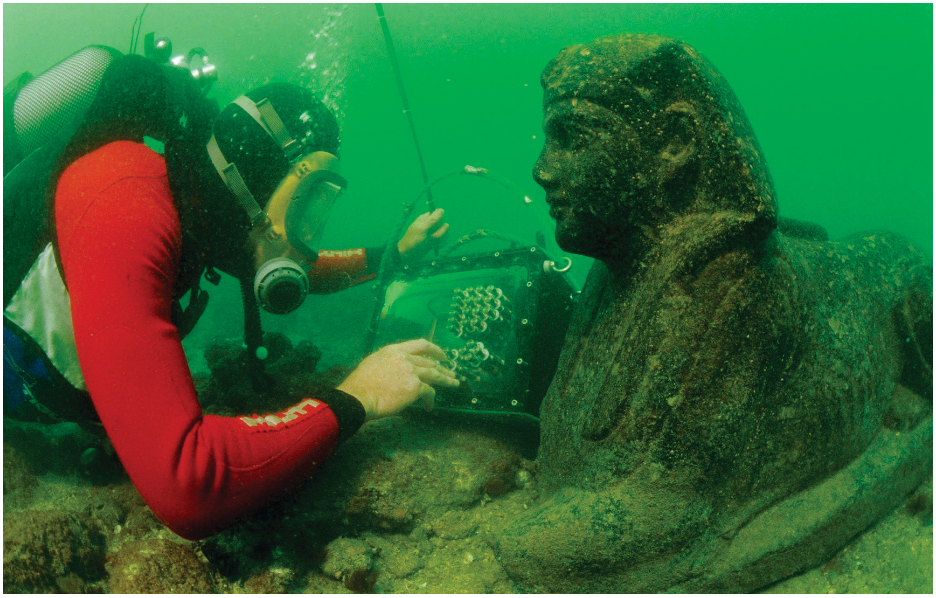


Plate 41. The team of the European Institute for Underwater Archaeology (IEASM) under the direction of Franck Goddio has made numerous discoveries in the eastern harbour of Alexandria. Among them is a sphinx made out of black granite. Its face is believed to represent Ptolemy XII, father of the famous Cleopatra VII. Image: Jérôme Delafosse, © Franck Goddio/Hilti Foundation

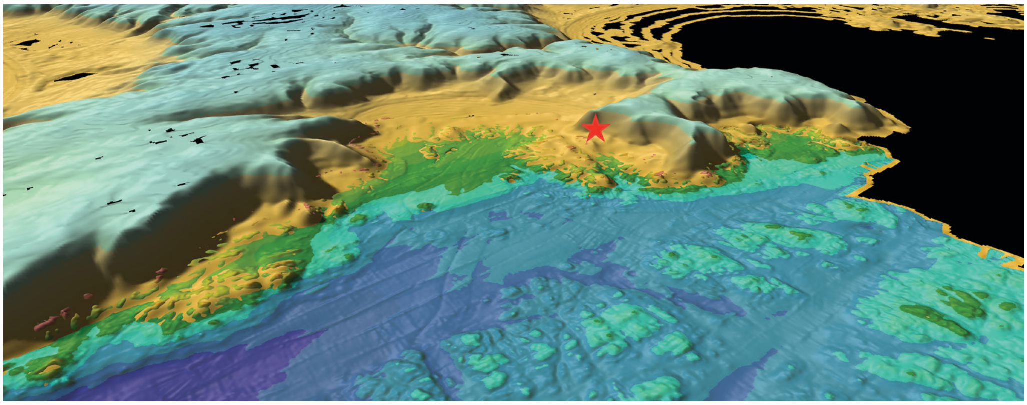


Plate 42. When the Neanderthal site of La Cotte de St Brelade (marked by the star) in Jersey is seen in its original setting with a lower relative sea-level it is possible to see how a narrow gully leads up to the rock fissure, to provide an ideal blind for hunting mammoth. Image: Richard Bates, University of St Andrews

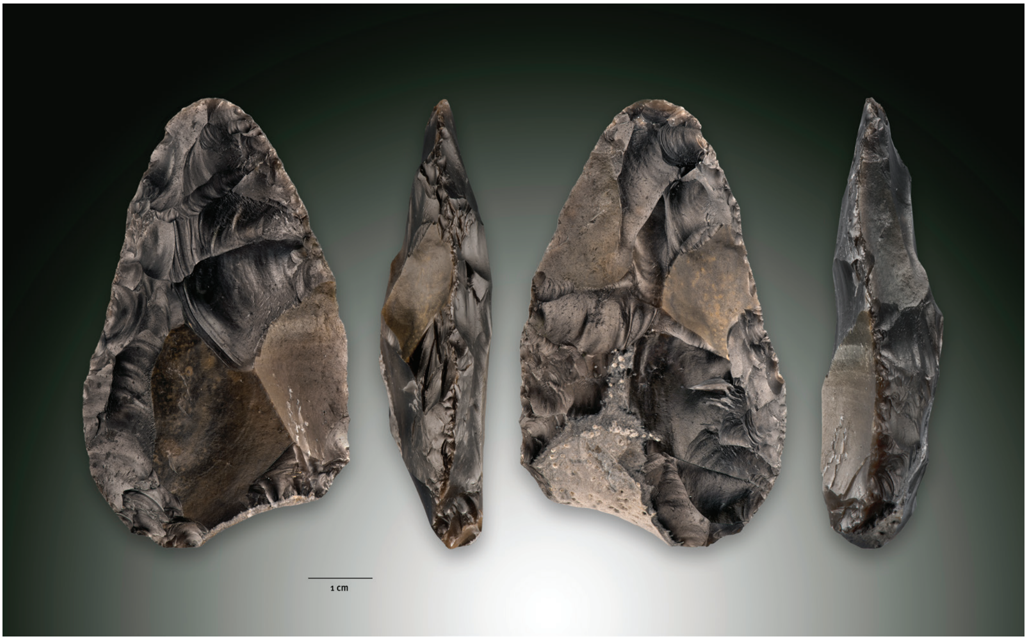


Plate 43. A fine, late Middle Palaeolithic flint handaxe (around 50,000 years old), recovered by Mirjam Kruizinga, during sand replenishments at Maasvlakte 2, an extension of the port of Rotterdam. Image: Frans de Vries (ToonBeeld/Oosterwolde)

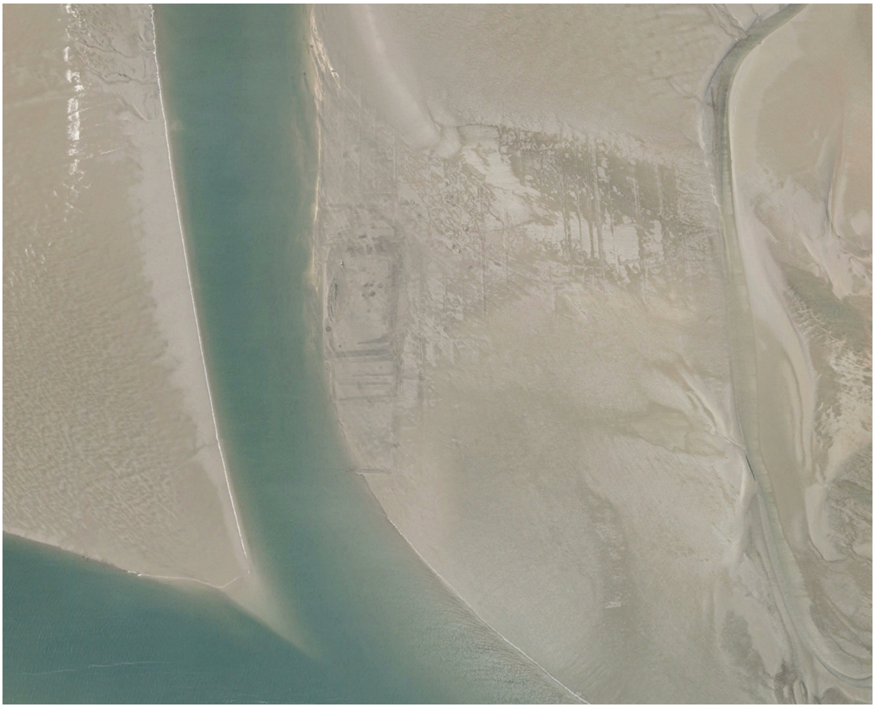


Plate 44. Intertidal flats to the north of the island of Pellworm, Germany. In this Google satellite image the traces of a medieval farming settlement close to a tidal channel may be seen as rectilinear features just to the left of centre. Image: Google Earth, © 2015 DigitalGlobe

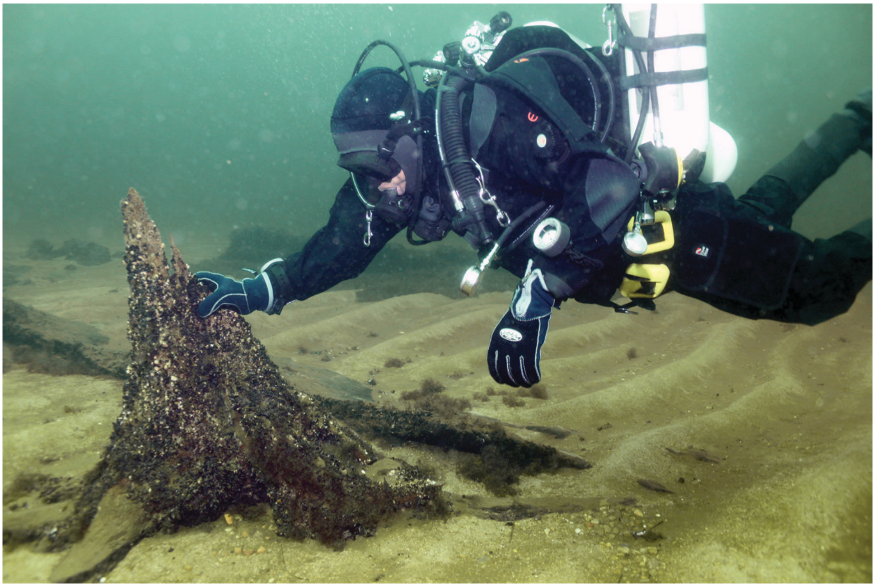


Plate 45. Haväng, Hanö Bay, Sweden, diver inspection of submerged tree remains. Image: Arne Sjöström, Lund University

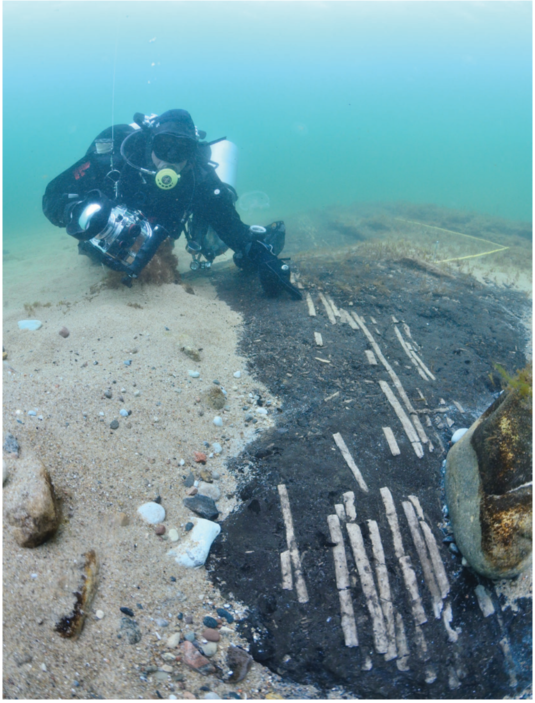


Plate 46. Haväng, Hanö Bay, Sweden, the remains of a fish trap made of hazel rods. Image: Arne Sjöström, Lund University

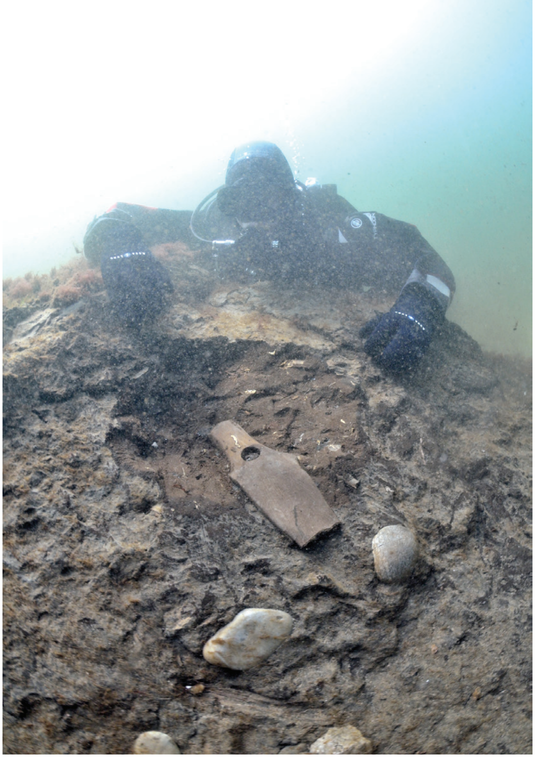


Plate 47. Haväng, Hanö Bay, Sweden, investigation of an axe of elk antler dating to c. 8900 BP. Image: Arne Sjöström, Lund University

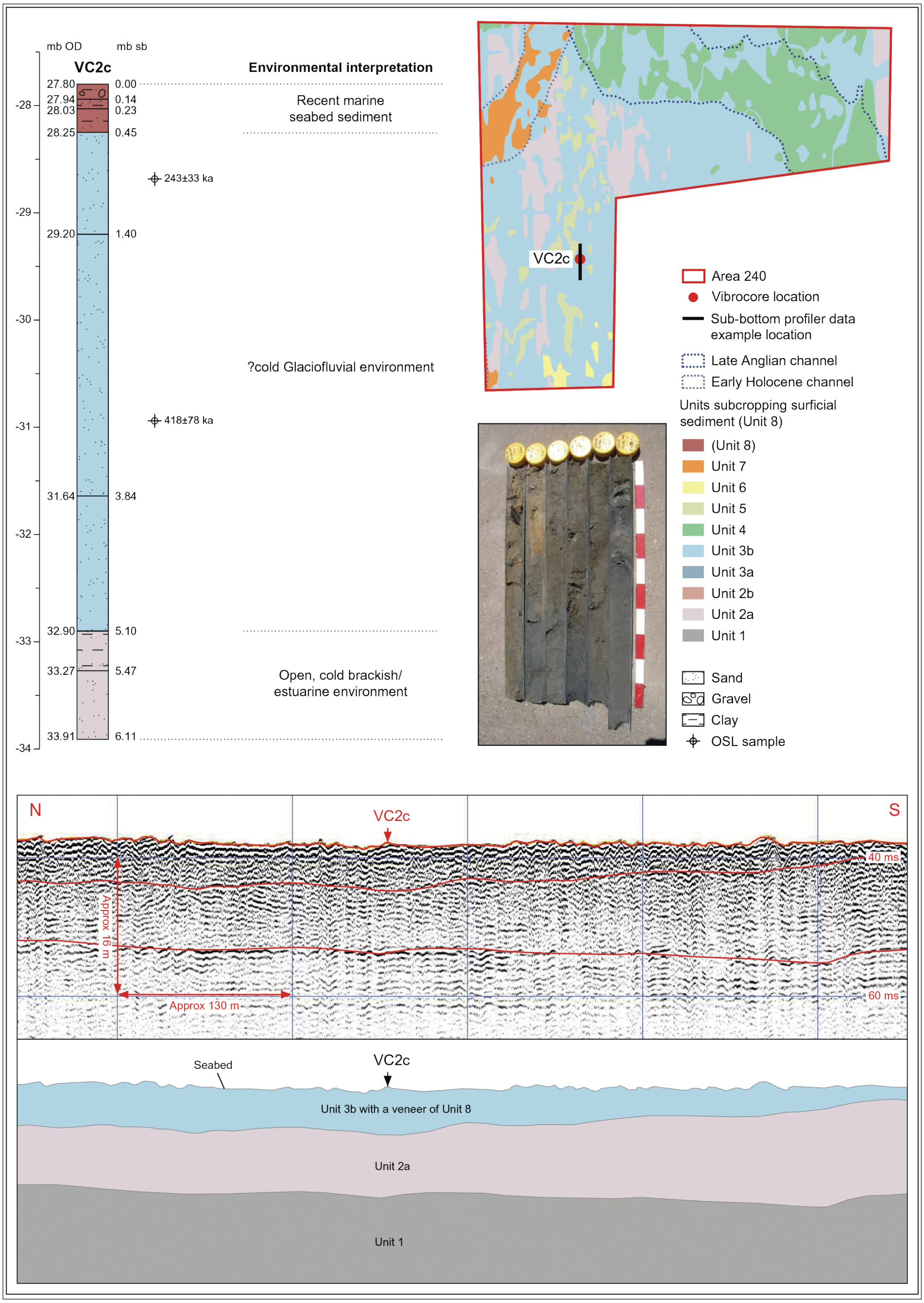

mb OD
mb sb
VC2c
Environmental interpretation
27.80
0.00
-28
27.94
0.14
28.03
0.23
Recent marine
seabed sediment
28.25
0.45
243±33 ka
-29
29.20
1.40
-30
?cold Glaciofluvial environment
-31
418±78 ka
31.64
3.84
-32
32.90
5.10
-33
33.27
5.47
Open, cold brackish/
estuarine environment
33.91
6.11
-34
VC2c
Area 240
Vibrocore location
Sub-bottom profiler data
example location
Late Anglian channel
Early Holocene channel
Units subcropping surficial
sediment (Unit 8)
(Unit 8)
Unit 7
Unit 6
Unit 5
Unit 4
Unit 3b
Unit 3a
Unit 2b
Unit 2a
Unit 1
Sand
Gravel
Clay
OSL sample
N
VC2c
S
40 ms
Approx 16 m
Approx 130 m
60 ms
Seabed
VC2c
Unit 3b with a veneer of Unit 8
Unit 2a
Unit 1

Plate 48. This technical illustration shows one of the sample cores from Area 240, the seismic context taken around it, and the resultant interpretation from the Area 240 research. Image: © Wessex Archaeology

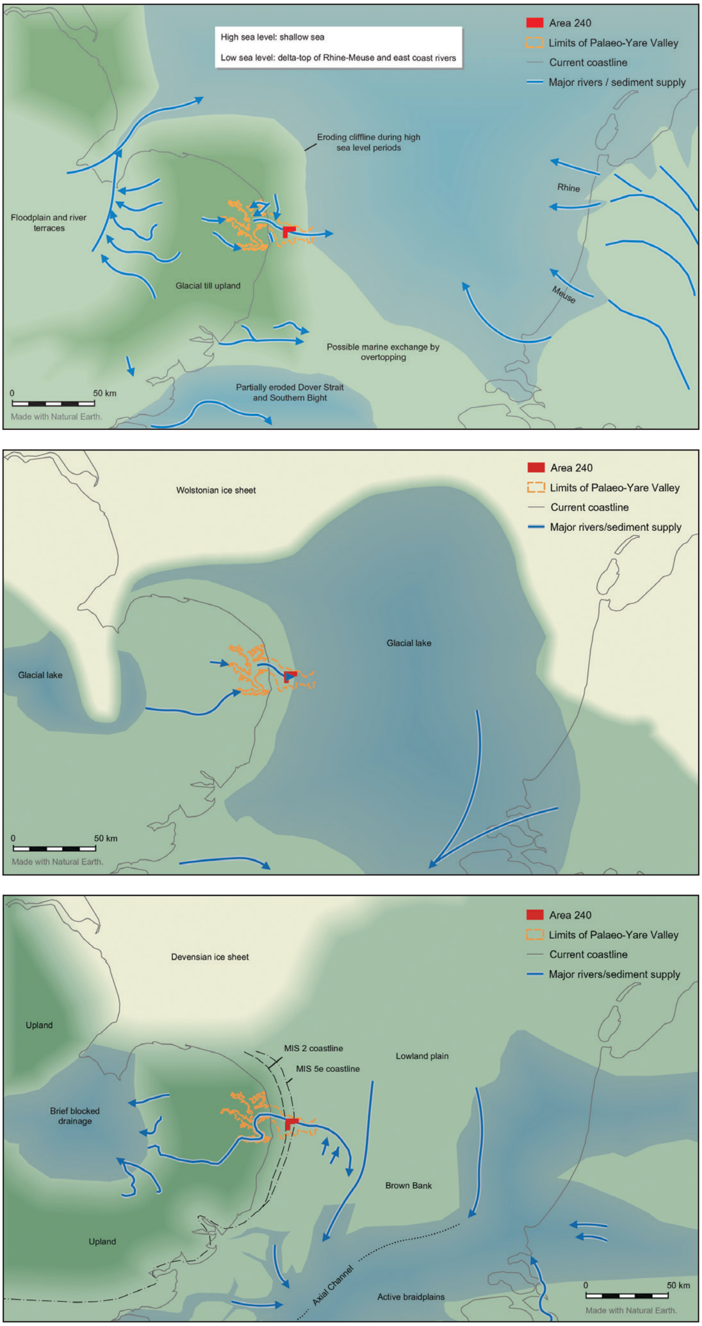

Area 240
Limits of Palaeo-Yare Valley
Current coastline
Major rivers / sediment supply
High sea level: shallow sea
Low sea level: delta-top of Rhine-Meuse and east coast rivers
Eroding cliffline during high sea level periods
Rhine
Floodplain and river terraces
Glacial till upland
Meuse
Possible marine exchange by overtopping
Partially eroded Dover Strait and Southern Bight
0
50 km
Made with Natural Earth.
Area 240
Limits of Palaeo-Yare Valley
Current coastline
Major rivers/sediment supply
Wolstonian ice sheet
Glacial lake
Glacial lake
0
50 km
Made with Natural Earth.
Area 240
Limits of Palaeo-Yare Valley
Current coastline
Major rivers/sediment supply
Devensian ice sheet
Upland
MIS 2 coastline
MIS 5e coastline
Lowland plain
Brief blocked drainage
Brown Bank
Upland
Axial Channel
Active braidplains
0
50 km
Made with Natural Earth.

Plate 49. Area 240, the interpretation of the developing palaeogeographic context through time. a) the Late Anglian glacial to the Saalian glacial, c. *450,000–190,000 BP; b) During the Saalian glacial, 190,000–120,000 BP; c) From the Ipswichian interglacial to the late Devensian glacial, 120,000–25,000 BP. Image: © Wessex Archaeology*

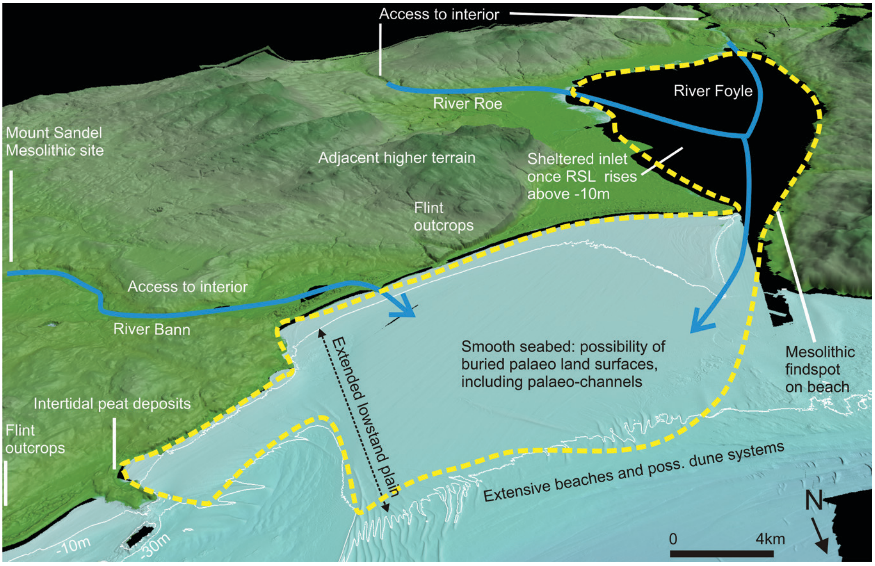

Access to interior
River Roe
River Foyle
Mount Sandel Mesolithic site
Adjacent higher terrain
Sheltered inlet once RSL rises above -10m
Flint outcrops
Access to interior
River Bann
Extended lowstand plain
Smooth seabed: possibility of buried palaeo land surfaces, including palaeo-channels
Mesolithic findspot on beach
Intertidal peat deposits
Flint outcrops
Extensive beaches and poss. dune systems
-10m
-30m
0
4km
N

Plate 50. Digital terrain model to indicate archaeological potential in the Mesolithic, around the estuaries of the Rivers Bann and Foyle, north coast of Ireland. Image: Kieran Westley, Ulster University. From Westley et al. *(2011)*

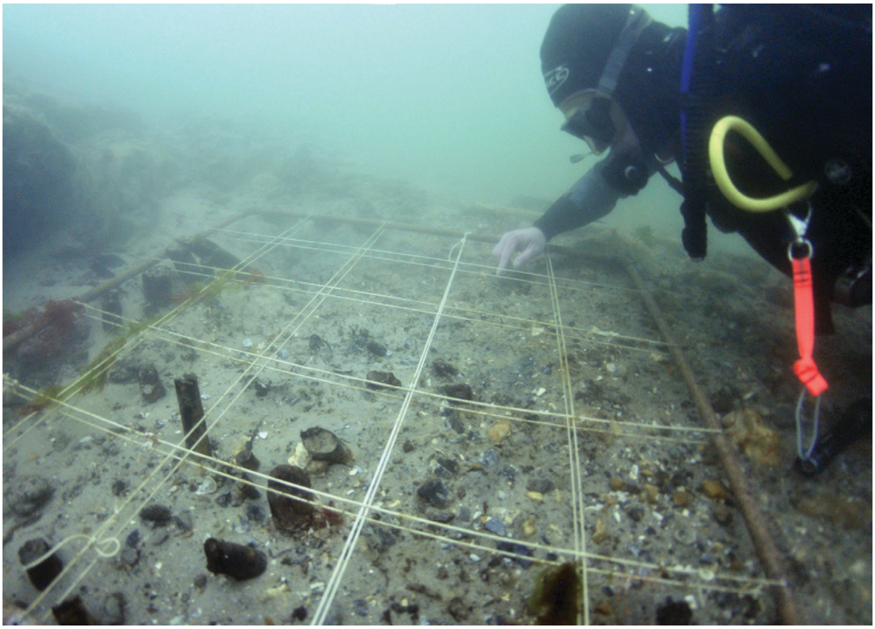


Plate 51. Bouldnor Cliff. Director Garry Momber inspecting exposed Mesolithic material during excavation of the site. Image: Roland Brookes, Maritime Archaeology Trust

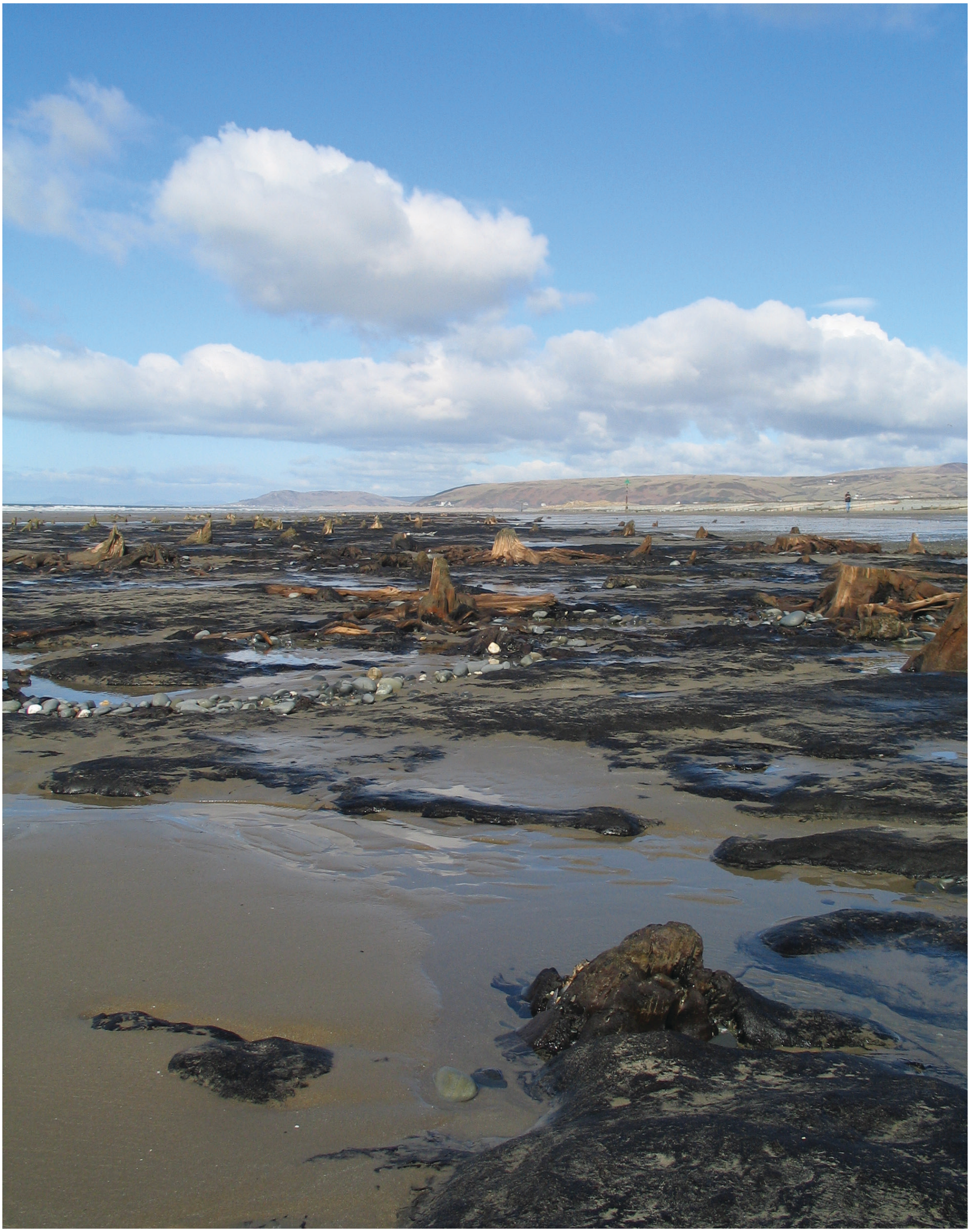


Plate 52. Tree stumps within the intertidal peat beds at Borth, Wales. Image: Martin Bates, University of Wales, Trinity St David

Plate 53. Loch Langabhat in the Island of Lewis, Western Isles, is typical of the landscape where survey in the lochs has revealed a wealth of well-preserved remains from the Neolithic. Image: Rodrigo Pacheco-Ruiz

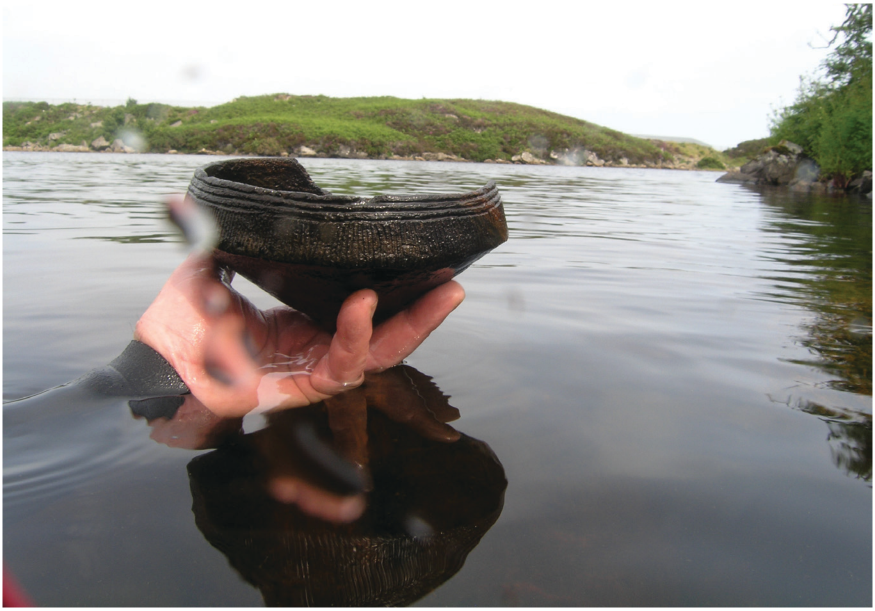


Plate 54. An Early Neolithic bowl recovered from Loch Arnish, Isle of Lewis, Western Isles. Image: Chris Murray

7. Methodologies II: Exploration and modelling

Diving

While diving is a useful technique that allows archaeologically trained personnel to examine first-hand the remains that may survive on the seabed, most submerged landscapes have been preserved below the actual sea floor. In coastal waters, diving can serve as a method to record traces of erosion faces or submerged cliff lines that provide information about past relative sea-level change even where further traces of the ancient landscape are now buried. Photographs, whether taken by remote vehicle, or hand-held camera provide a valuable supplement to elucidate details also observed in remote sensing. Generally, the great size and broad sweeps of most submerged landscape areas limit the value of work by individual divers even where features are visible. This means that diving is of more relevance to the study of individual sites.

Diving on specific submerged sites allows direct observation and recording of the site: by eye; photography: hand held or remote device; and traditional planning (Pl. 17; Fig. 7.1). Diving clearly adds a layer of specialisation to any project and when it is to be undertaken it is necessary to conform to the standards set down by both the Nautical Archaeology Society (Bowens 2009) and the Chartered Institute for Archaeologists (CiFA 2014). Appropriate training is necessary. As with work on land it is vital that archaeological divers be familiar with the type of site they are investigating. This may seem obvious, but many archaeological divers, while experts on shipwreck remains, know little of prehistoric stonework, or hunter-gatherer artefacts. Just as it would be rare to embark on survey work on land without some expertise in the types of site likely to be encountered, a lack of relevant experience will hamper recognition and investigation of underwater material. Submerged sites can be difficult to understand, partly because of the increased deterioration of material underwater, and the ability to eyeball remains and examine them first-hand, definitely enhances their interpretation.

Excavation

On occasion research and investigation may require the use of excavation. This is likely to be costly, and the complexities of tide, visibility, currents and weather can all combine

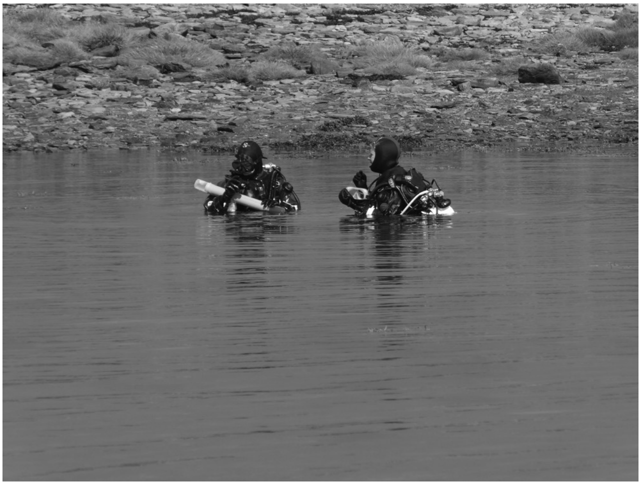


Fig. 7.1 Divers leaving the water with a completed core. Image: Richard Bates, University of St Andrews

to make it a process that is subject to more constraints than excavation on land. Underwater excavation is a technical process whose skills must be learnt just as with work on land. In many ways, the same principles apply, with the added complications that you are underwater, visibility may be poor, record keeping is more difficult, and you need special equipment to breathe (Pl. 18). The removal of finds from underwater sites is a specialised process that often requires enhanced conservation measures and equipment due to the potential for finding preserved organic remains. Nevertheless, many of the basic techniques used are surprisingly similar to those used in terrestrial archaeology, and the same overall recording principles will apply (Pl. 19).

Though any diver can, in principle, join an underwater excavation team, in order for it to be safe it is carefully controlled by guidelines and scientific divers need full health and safety certification. The Nautical Archaeology Society can help with this (https://www.nauticalarchaeologysociety.org/) and the UK Scientific Diving Supervisory Committee also provides guidance and useful links (http://www.uk-sdsc.com/archaeological.htm). Training courses in underwater survey and excavation take place around the UK in a variety of environments and on different types of site. The Chartered Institute for Archaeologists have a Marine Archaeology Special Interest Group that is a useful source of information (http://www.archaeologists.net/groups/maritime).

Just as with sites on land it should be borne in mind that excavation is destructive and should only be used as a last resort. Valid reasons to excavate include research situations where it provides the only way to answer very specific research questions, or rescue situations when material is going to be lost to development anyway. In the latter, the excavation becomes a matter of ‘preservation by record’. Underwater excavation is expensive, and projects should not be started before adequate funding for all elements of work including conservation, post-excavation analysis, reporting and archiving, has been assured. Careful recording is necessary, fragile finds need to be conserved, post-excavation research will be time consuming, the ultimate home for your finds needs to be considered in advance of excavation, archives should be kept up to date and deposited in a national record, and full publication is always necessary.

The many prospection methods available to underwater archaeologists allow for the gathering of considerable amounts of information without any destruction. In most cases, good prospection should be all that is necessary to learn about a site or landscape.

Case study

Bouldnor Cliff

Bouldnor Cliff lies on the northwest coast of the Isle of Wight, on the southern shores of the Western Solent. The location, at a depth of 12 m, and some 500 m from the coast, had been known since the late 1980s for the preservation of submerged tree remains together with associated peats, both of interest for investigation of the submerged landscape. In 1998, the Hampshire and Wight Trust for Maritime Archaeology began work to investigate the possible archaeological potential of the area, and this was soon rewarded by the discovery of worked flints. More flints were recovered in 1999 and the team soon realised that they had an exciting archaeological site on their hands. The nature of the flint work placed the site firmly in the Mesolithic period, around 8000 years ago, and this was confirmed by the palaeoenvironmental history of the area which indicated that the submerged landscape on which the site was situated had started to show the influence of rising relative sea-levels around 7000 years ago (Momber *et al.* 2011).

The Trust continued to make regular dives on the site and record eroding flint work, together with palaeoenvironmental material, and in 2003 English Heritage funded excavation here. Since then ongoing work has recorded several archaeological features, collected more stone tools, and undertaken extensive sampling in order to enable reconstruction of the prehistoric environment (Pl. 20). The features have included pits and possible hearths, but the most exciting aspect of the site is the preservation of considerable amounts of wood, including worked wood (Fig. 7.2). Analysis of the timbers has not only revealed evidence relating to the immediate environment of the site, but also of the ways in which timber was selected and worked for various purposes. One of these seems to have been boat building. The excellent preservation conditions also led to the survival of smaller objects such as lengths of string made of twisted fibres, and deposits of burnt hazelnuts.

Although many conventional underwater excavation techniques were employed at Bouldnor Cliff, the fast currents meant that it was also necessary to develop ways of working that were specific to the local conditions, and some of the material was removed in boxes, to be excavated in detail, and comfort, in the laboratory. Bouldnor Cliff is an exciting site that illustrates the possibilities for the preservation underwater of early prehistoric material around the UK, even in areas of relatively high energy waters. The remains lie in a linear band, within extensive pockets of peat and other organic materials at the foot of a submerged cliff line (Pl. 21). It has not always been easy for the archaeological divers to relate one find spot to another along the cliff. Given the lack of information relating to many aspects of life at this early date from sites on land, such as woodworking and boat technology, the persistence of the work underwater has paid off.

In recent years, investigation at Bouldnor Cliff has pioneered the investigation of submerged sediments for the presence of ancient DNA (Smith *et al.* 2015). While this yielded promising positive results in terms of aDNA related to animals such as dogs or wolves, aurochs, and deer, it also yielded thought-provoking material suggesting the presence of an early form of wheat dated to some 2000 years earlier than it has so

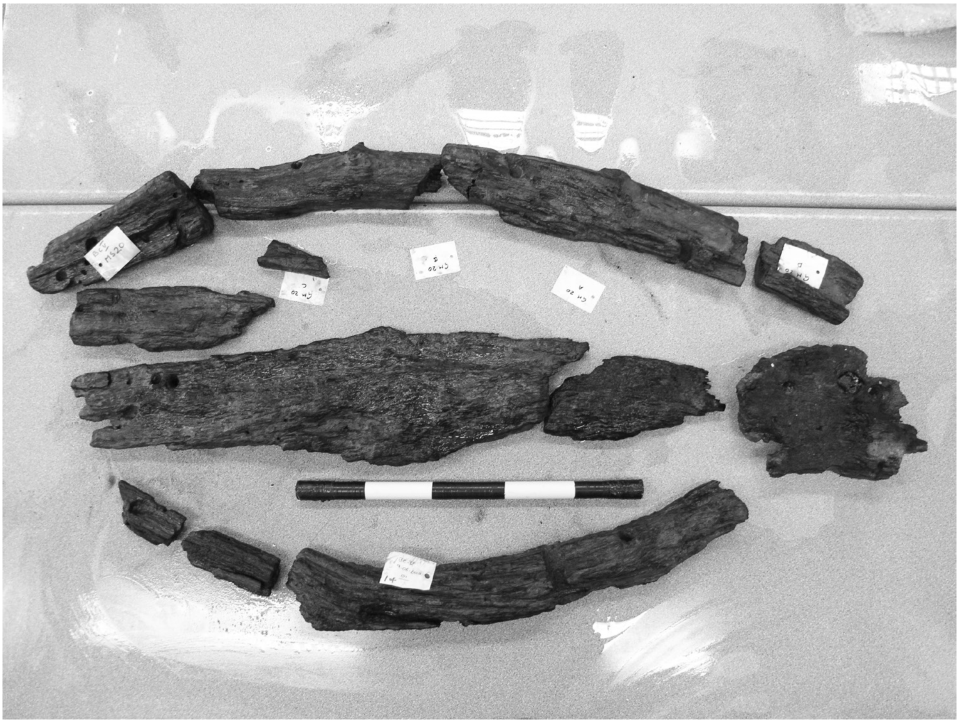


Fig. 7.2 Bouldnor Cliff, wooden finds from the site. Image: Garry Momber, Maritime Archaeology Trust

far been found elsewhere in the British Isles. This has still to be replicated elsewhere, but it is a good example of the way in which information from submerged sites and landscapes can prove challenging to conventional interpretations of prehistory.

Coastal survey

Features relating to submerged landscapes often protrude above the present sea-level and thus may be studied by more conventional means. Relevant material might include deposits of ancient peat, or intertidal forests, as well as old cliff lines, eroded dune systems, or even ancient water courses. Elements such as these may be an indication that other remains have been preserved offshore. In these cases, conventional archaeological survey work can be used to record the features relating to the ancient landscape on land and it is then possible to tie these into information relating to the submerged landscape either using high resolution bathymetry and GIS modelling, or, more accurately, information derived from seismic profiling and GIS.

Work such as this is of considerable value not only because it helps to place existing finds into their proper geographical context, but also because it assists heritage management by predicting the likely location of new finds and identifying areas of high archaeological potential and possible environmental fragility.

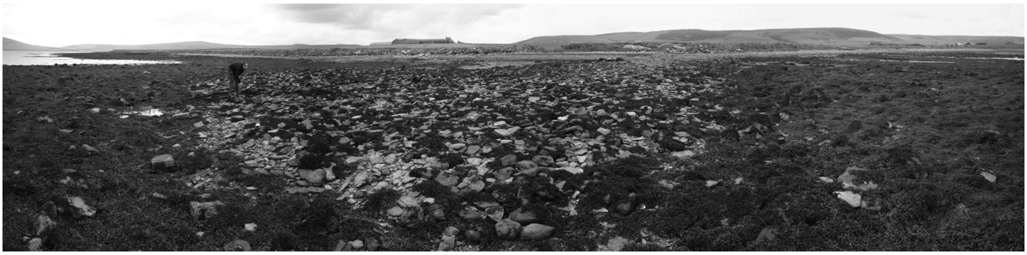


Fig. 7.3 Bay of Firth, Orkney, investigating sites on the foreshore, here a low platform of stone and slag

The study of coastal features is also relevant to our understanding of archaeological material on the seabed. In many places, the remains of numerous sites litter the intertidal zone, often unrecorded. These may mimic the types of site that potentially occur underwater in an area, and, by recording them, it is possible to obtain information relating to the decay of humanly-built features. For example, the observation of collapsing stone walls and buildings on the foreshore can provide important evidence relating to the behaviour of structures built of local stone during the process of inundation (Fig. 7.3). Even well-preserved prehistoric structures of stone can quickly be reduced to piles of seaweed-covered rubble underwater, and it becomes hard to distinguish between natural and anthropogenic features. Close recording of material along the coast facilitates recognition of relevant features on the seabed (Bates *et al.* 2013a). In places, it may even be possible to observe prehistoric sites as they succumb to inundation.

Case study

Ramore Head, Portrush, Ulster

The peninsula of Ramore Head on the north coast of Northern Ireland projects into high energy waters where the mean wave heights can exceed ten metres in the winter. Despite the fact that the local conditions and existing high resolution bathymetry might suggest that the potential for submerged landscape studies here was poor, Kieran Westley and his colleagues at the University of Ulster, Coleraine, initiated a research project here, sparked partly by local finds of flint work which indicated that this area was a significant location in the Mesolithic, and partly by the existence of intertidal and coastal peats likely to be associated with changing conditions during a period of rising relative sea-level (Westley *et al.* 2014).

In addition to examination of the existing peat deposits, the project made use of recently-collected high-resolution bathymetry, supplemented by seismic profile data that had been already acquired for a mix of research and commercial purposes. From this, it was possible to construct a sequence of three-dimensional digital terrain models relating to the topographic surface of the submerged landscape as it lay beneath the present sea floor. More precise data relating to the submerged landscape could then be added through the analysis of samples extracted from a number of sediment cores taken for commercial purposes in recent years. Although interpretation was limited by the lack of precise data relating to the rate and extent of past relative sea-level change around Ramore Head, it was possible to produce a palaeo-geographical reconstruction of the landscape at various points in prehistory (Pl. 22). In this way, the team were able to identify the ancient, landscape as it extended out below the present bay at the start of the Mesolithic. They could then build models to show how it had subsequently transgressed to about three metres above the present sea-level in the late Mesolithic.

Ethnoarchaeology

Ethnoarchaeology relates to the study of current societies in order to interpret the communities of the past. One of the most influential practitioners was Lewis Binford whose work on the Nunamiut of Alaska became a seminal influence on hunter-gatherer studies relating to early prehistory in high latitudes (Binford 1978). Binford focussed on material goods and the way in which they were used to articulate everyday life and culture and he related his findings to the interpretation of hunter-gatherer sites across the world. In recent years, the discipline has expanded to include research on a very different aspect of community life and it has extended its reach to cover the investigation of information relating to communities closer to home as well as more exotic societies.

Ethnoarchaeology, today, can also relate to the study of our own communities and it includes the collection and analysis of oral histories and stories. Every society around the world makes use of stories. All too often the labelling of these can be misleading, defining them as 'fairy stories' or 'legends', but in reality, stories are the way in which people make sense of their world. They certainly contain made-up narratives, but there is often an element wherein fragments of reality exist in the use of place names or, sometimes, events (Cruikshank 1990; Knapp and Ashmore 1999). The trick is to identify those fragments and separate them from their imaginary context.

In many locations researchers have recorded stories that appear to relate to topographical depictions of places that no longer exist and, in some places, this has been related to the changes introduced by past relative sea-level change. Research in Haida Gwaii is investigating the correlations between the rich oral history of the inhabitants of the islands and past environmental change including post-glacial sea-level change (Fedje and Mathewes 2005). In Atlantic Canada, Lacroix and his colleagues have recorded stories relating to the intrusion of tidal waters into the Minas Basin, an expansion of the Bay of Fundy (Lacroix *et al.* 2014).

The unpicking of ethnoarchaeological information is, however, tricky and highly specialised. It is, of course, impossible to prove the inspiration behind any tradition, and it is very easy to find links where we want to see them. Sometimes, the apparent explanation for a story can owe more to 21st century rationalisation than to the observations of the past. It is a nice idea to think that our ancestors were the meticulous observers of natural events and that they wove them into their lifeways, but it is not always true. Furthermore, stories naturally evolve in the telling and they can migrate as they transform. Material that might seem very relevant to one location may have developed some distance away and been adapted to fit another scenario. In Ceredigion in Wales there are strong legends around a land known as Cantre'r Gwaelod which appears to have extended out to sea in times past (Doan 1981). Research along the coast here indicates that lower relative sea-levels did result in the existence of a more extensive coastal plain in the Early Holocene, and evocative evidence of the apparent existence and nature of Cantre'r Gwaelod would appear to be provided by sites such as Borth where the impressive remains of an ancient forest in the intertidal zone of the present beach may be visited (Godwin and Newton 1938; Hughes and Schulz 2001). However, research on the legends of Cantre'r Gwaelod indicates that they are likely to incorporate many different strands, some of which originated outside of the area (Kavanagh and Martin Bates pers. comm. May 2017). It is a difficult job to unpick the local material from that which has been imported, so that it is not possible to make a direct one to one parallel between the legends of Cantre'r Gwaelod and the forests of Borth.

The picture is further clouded by the way in which new discoveries in archaeology are often ascribed ancient 'meaning' in an attempt to attract popular attention. In this way, records of flooding events in the Black Sea obtained from geoscience investigations have often been linked to the Biblical story of Noah's Flood (Ryan and Pitman 2000) and information on Doggerland is sometimes labelled as Britain's Lost Atlantis (Waugh 2012). Although this is admirable in terms of facilitating public engagement, it undersells the academic interpretation of the data. In the absence of quantifiable research on Noah's Flood and Atlantis, links like these can never be more than anecdotal.

Ethnoarchaeology is thus an interpretive tool that needs to be used with care. It has considerable potential to provide colour and facilitate understanding of past events. However, it is important to avoid ascribing spurious certainty to the legends of the past. For a story to be relevant it has to be shown to have originated in the area concerned and, where possible, quantifiable data, appropriate to specific events should be included.

Case study

Orkney

The Rising Tide project works to investigate past relative sea-level change in Orkney and has included research to integrate information from oral history and archive material with data from sediment coring and remote sensing (Bates *et al.* 2013). In the late 19th century, a local antiquarian, Walter Traill Dennison, put together information relating to the island of Sanday, one of the northern isles of Orkney, which seemed to describe a time when the local sea-level was lower and gradually encroaching on the island (Muir 1995). This was supplemented by Alistair Rennie when working for his PhD on the same island as he gathered together traditional poems and stories that related to locations along the coast that no longer existed but could be identified on the charts (Rennie 2004).

Rennie quotes an old, anonymous, Sanday poem that refers to 'The horse buils o'Riv', while Traill Dennison notes a story that sometime in the century prior to 1851, local people were accustomed to driving their horses across the intertidal zone to the Holms of Riv where they would graze. The Riv today is a rocky skerry that barely pokes above the lowest tides. There is, as yet, no data to indicate when the Riv last supported grass, but we do know that relative sea-levels around Orkney have been steadily rising throughout the Holocene. As there has been no detailed academic research on the oral traditions of Sanday, the interpretation remains speculative and vague. It is possible that the story has been brought to Sanday and adapted to fit the local geography, even to explain half-remembered changes in the island geography. But there is clearly scope for investigation of the development of oral history in the island and to consider the possibility that places like the Riv would have been terrestrial during the early occupation. Rennie's work mentions several other locations in Sanday, including the submerged fossil forest of Otterswick which he dated to around 6500 BP. 'The woods o'Otterswick' are also mentioned in the poem, adding weight to arguments that these particular oral traditions may reach back to a time when the geography of Sanday was quite different.

Other examples of ethnographic history, relating to other parts of Orkney, have been also been recorded. With regard to the Bay of Firth, at the heart of the Orkney Mainland, Firth, in 1920, noted:

> A skerry running from the point of Damsay to the shore of Coubister, which, except for a small channel, is a barrier to deep laden vessels, tradition says was at one time above high-water mark and was passable for pedestrians, but on a funeral procession crossing and resting the bier when half-way over, the skerry sank down to its present level. (Firth 1920, 137)

The skerry at Coubister exists today, and is still a barrier to shipping; research suggests that it has not been easily passable since around 5000 BP, when it would have been covered by shallow waters at high tide (Bates *et al.* 2013). Google Earth clearly shows a structure running along the skerry and the possibility remains open that Firth was recording a tradition that held considerably greater antiquity than he realised. The Bay of Firth has attracted several stories relating to past differences in the level of the sea and the collection is still growing; local divers today relate accounts of mysterious structures below the waves here, though to date it has proved impossible to verify any of them (Bates *et al.* 2013).

The detailed veracity of any of these stories is hard to prove, and, often, unlikely. Yet, taken together these accounts provide a colourful, and convincing, narrative suggesting that there was, indeed, a time when the geography of the archipelago of Orkney was not as it seems today. They also suggest that this time coincided with the early human inhabitation of the islands. This, interestingly, is borne out by geoscience research (Wickham-Jones *et al.* 2016).

Modelling: Digital Terrain Models (DTM)

Investigation of the submerged landscape usually involves the production of large data sets derived from survey work and core analysis. In order to convert these into visual representations of the past topography and environment, it is common to model them through the use of Geographic Information Systems (GIS) such as ARC-GIS or Q-GIS. Programs such as these can be used to amalgamate related sets of data into one output, such as a digital terrain model, that replicates the look of a map. These representations can be two-dimensional or three-dimensional. Because they are not based entirely on actual data coverage, it is important to remember that, no matter how much it looks like a map, a digital terrain model is a model, not a map. Digital terrain models rely on the use of as much data as possible, together with careful projections of the likely situation where data does not exist, in order to fill the gaps, for example projections of likely changes in relative sea-levels due to eustatic and isostatic rebound at the end of the last Ice Age. The models will only be as accurate as the data and the research projections that are put in to them, though it is, of course, possible to produce images that give the superficially familiar appearance of a map.

Modelling is a useful tool for archaeology, which assesses the relationship between people and the land in which they live. Because of our familiarity with maps, the visual nature of the output can facilitate consideration of the population within an area and likely human responses to the terrain and inundation. For example, digital terrain models of the Pentland Firth in early prehistory emphasise the narrow nature of the entrance to Scapa Flow and the high cliffs on either side. Add to this information relating to the fast-flowing present-day, and likely-prehistoric, currents in the area, together with information on prehistoric sea-craft, and it is easy to imagine how those crossing the Firth in small boats would have felt when being propelled between the high cliffs to either side of the present-day Sound of Hoxa and into the calmer waters of Scapa Flow beyond. Though it is a physical image, modelling can help to approach consideration of the emotional reactions of the past (Wickham-Jones *et al.* 2018).

In this way, modelling is useful for interpretation and public presentations, but it does have a downside in that it can be easy to forget that the visual image relates to a model and not a map. Nevertheless, without modelling, it would be impossible to undertake the interpretation of the submerged landscape and for this reason it provides a significant archaeological tool. Vince Gaffney and his colleagues provide a useful account of the integration and visualisation techniques that they used in order to model the submerged landscapes of Doggerland (Gaffney *et al.* 2007). They have subsequently developed this to introduce elements of human behaviour in order to provide archaeological relevance for their interpretations (Ch'ng and Gaffney 2013).

Predictive modelling

Modelling is also used to help with the prospection for sites on the seabed. There are two ways in which this can be done, and both combine pre-existing information relating to the landscape before submergence with information relating to the type of site that might occur. Both rely on the principle that there are universal laws for human behaviour: that if one community has used a specific location in a particular way, then similar communities elsewhere are likely to use similar locations in similar ways. One method relies on an instinctive understanding of the way in which prehistoric communities may have used that landscape, and the other method uses the analysis of quantitative data relating to the location of prehistoric sites in an area.

The best example of the use of instinctive modelling lies in the application of the 'Fishing Site Model' to the prospection for submerged Mesolithic sites in Denmark in the 1990s (Fischer 2007). Mesolithic sites can be hard to find on land; their location underwater is even more difficult and in the 1980s the archaeologist Anders Fischer started to test the correlation he had noticed between productive places for fishing today and archaeological finds of Mesolithic sites. Armed with a reconstruction of the submerged landscape, Fischer was able to predict with some success the likely locations for Mesolithic sites in the waters at the entrance to the Baltic, based on the suitability of the locations for fishing. Fischer was relying on the assumption that fishing was a mainstay of the way of life for the Mesolithic communities in question and that their assessment of a good fishing spot would approximate to the assessments of the 20th-century fishing community. In this case, the model worked well, and it has since been applied in other locations (Benjamin 2010).

Nevertheless, this sort of modelling does have limitations. It relies on the assumption that the factors governing a specific aspect of behaviour today also governed that behaviour in the past, even across wide geographical areas and differing communities. It tends to focus on one aspect of behaviour, to the detriment of others, and assumes that settlement choice is limited by a single factor. Application of an instinctive model reduces different geographical areas to facsimiles of one another, whereas there are always, of course, many interconnecting variables. And, of course, different people may have different ideas about the significant factors even within one aspect of life. Finally, the focus on matching locations can lead to a misleading sense of accuracy as it becomes difficult to locate sites that do not follow the model. Few projects have tested the null hypothesis. In Denmark, more recent analysis indicates that many Mesolithic sites do not conform to the 'Fishing Site Model' (Grøn 2015).

Predictive modelling with quantitative data makes use of the accumulation of precise data sets relating to many different aspects of site location such as the distance from fresh water, slope, ground conditions, prevailing wind direction, distance to the coast and type of coast. The collection of data relating to many separate sites makes it possible to draw up rules of site location, perhaps applying parameters of probability, that sites are more likely to be located within twenty to forty metres from fresh water for example. Using a GIS programme and digital terrain model of the underwater landscape it is then possible to highlight the specific areas that conform to an individual rule and by adding information relating to all aspects, so it is possible to predict those locations in which sites are most likely to be found.

While this method has the advantage of using quantifiable data, it still has limitations. Once again it assumes that there are universal rules of human behaviour, whereas research indicates that different groups can behave in very different ways even when apparently exploiting the same resources (Grøn 2012). It also ignores the fact that known archaeological sites only represent a small percentage of the original number of archaeological sites. Many sites have been destroyed, others remain to be found. There are many different factors that affect the makeup of the archaeological record today and they do not necessarily relate to the reasons why a prehistoric community chose to locate their settlement in a precise location. We may, for example, be finding more sites in specific parts of an eroding coast, than in others where field survey is more difficult.

While predictive modelling can be a useful tool to provide an idea of possible locations for sites in the underwater landscape, it is important to remember that sites may also occur outside the predicted zones. In general, modelling can be used to give an idea of broadscale locations worthy of further prospection, but it should never be used as a tool for site location on its own.

Agent-Based Modelling

A further form of modelling, known as Agent-Based Modelling (often shortened to ABM) incorporates known aspects of appropriate human behaviour into information about the terrain and likely resources and uses time-based simulations to calculate how this behaviour will play out over a number of years, or even centuries, within a defined area of land (Wurzer *et al.* 2015). While this is often regarded as an interpretative tool, it can also be used to predict the types of terrain that might be of interest to a group, and thus it becomes a management or site location tool (Pl. 23). This application of modelling is still highly speculative, and refinements are ongoing, but it adds extra dimensions to predictive modelling and is likely to be of use in future (Cegielski and Rogers 2016).

Aerial photography

In shallow, calm waters excellent results have been obtained using conventional aerial and satellite imagery in order to 'see below the waves' and view submerged features and landscapes (Pl. 24). It is always worth examining archives of aerial photography for coastal waters; often different weather and tidal conditions will reveal different features. Many archives, such as those of Historic England, Historic Environment Scotland, local councils or the Archaeological Data Service, contain sets of aerial photographs, often taken for different purposes and at different times.

Satellite images, such as those on Google Earth can also provide useful sources of information, though the resolution of Google Earth varies and resolution in more remote areas can be too low to be of much use. Nevertheless, it is worth keeping an eye on it because these resources are frequently updated. Shallow water sites such as ancient fish traps are often recorded on satellite images (for example a series of fish traps in Applecross Bay, Scotland, Pl. 25).

Archives

Library, university, local council, heritage and other archives can all hold information relevant to the submerged landscape. This may be information relating to past surveys such as bathymetric surveys, or information relating to activities that have impinged on the underwater zone. Annotated bathymetric charts, research notes, even letters and diaries can all hold useful comments. These may relate to the location of sites: such as divers' reports of unusual features, or to past landscapes: such as accounts of access to locations that are no longer visible; or they may help to interpret underwater material: such as old records from fish and shellfish farms that no longer exist.

8. Managing submerged sites and landscapes

The identification of archaeological sites on the seabed

The identification of archaeological sites on land is a specialised process and not always easy. Underwater, it can be even more difficult. Most submerged sites tend to relate to earlier periods of archaeology, and in particular to hunter-gatherers, meaning that they are unlikely to contain built and structural remains. Hunter-gatherer sites, whether on land or underwater, are often composed merely of post-holes and pits, together with the remains of hearths, and occasionally anthropogenic sediments such as occupation deposits. Finds comprise flaked lithics, coarse stone tools such as hammer stones, and, sometimes, burnt hazelnut shell. Organic artefacts are usually rare on terrestrial sites but may survive underwater – finds ranging from logboats to string have been recorded on submerged Mesolithic sites in Europe. Human skeletal material, often lacking on terrestrial sites, is a component of several submerged sites, perhaps a reflection of their specific locations as much as of the improved preservation conditions. Despite these successes, on initial recognition most archaeological sites underwater do not look promising.

Even where built stonework is present, the situation is not necessarily much better. Where structures are built of local stone, it can be difficult to distinguish between built and natural accumulations of material. This is particularly the case in Orkney, where rising relative sea-levels have worked to inundate considerable tracts of the archipelago throughout the Early Holocene, only reaching the levels of today some 3000 years ago (Bates *et al.* 2013a). The longevity of this landscape change means that there is a possibility that some stone-built Neolithic sites similar to the farmstead at Knap of Howar on Papa Westray, or the tomb at Unstan, will have been submerged. Despite the apparently robust nature of these later monuments, research on the seabed has found that the distinction between collapsed walling and natural bedrock is hard to make, particularly when the site is covered by abundant seaweed (Bates *et al.* 2013a).

The situation is further complicated by the likelihood that submerged sites will be subject to erosion or covered by sediment. Taphonomic processes such as these can be particularly active underwater and serve to obscure remains. As the seabed is an active environment, even locations familiar from repeated survey work can change in aspect in a short space of time. Sophisticated systems of remote sensing and investigation help to mitigate this, but it is not easy to find sites underwater, and, once found, they do not always look spectacular (Pls 26 and 27).

In some places, of course, spectacular remains are located, as with the submerged remains that relate to the ancient Egyptian city of Alexandria and other urban locations at the eastern end of the Mediterranean (Pl. 41; Robinson and Wilson 2004).

Fragility and threat

Submerged sites and landscapes are fragile, and they vary in scale, just like their counterparts on land (Pl. 29). In general, their survival today is due to the fact that they have not been disturbed over the millennia. The increasing development of the seabed means that many sites are now at escalating risk of disturbance and even damage (Evans *et al.* 2009). Seabed development takes many forms from extractive industries such as oil extraction, aggregate dredging or inshore maintenance dredging for harbours and marinas to construction such as the erection of structures for renewable energy turbines (both wind and water) and the accumulation of infrastructure such as cables, pipelines, and anchorages. After millennia of relative stasis, there is now increasing pressure on the underwater zone.

Activities such as these pose a varied threat to cultural heritage remains, including both localised actions: direct damage; destabilisation; loss of artefacts, and broader scale actions: the destruction of relationships and context; erosion. Many types of activity and construction have been identified as potentially damaging or destructive to archaeological remains, and the following lists are not comprehensive, but they provide an idea of the variety of activities under consideration.

- Coring of the seabed
  - Prospection for oil, gas and other resources
  - Foundation engineering for platforms and other structures
  - Investigation in advance of pipe and cable routes
- Drilling
- Pile driving
- Construction
  - The emplacement of platforms and other structures. It is important to consider the total footprint of the platform, including that of any associated support systems.
  - Permanent anchors for semi-submersible platforms
  - Temporary anchorages
  - Nearshore structures including outflows and emplacements
- Extraction
  - Aggregates
  - Dredging: capital and maintenance
- Pipe trenching
- The laying of cables
- Coastal trenching

- Coastal structures, terminals, docks, shoreside structures, jetties
- Trawling and other fishing activities
- Movement (including dumping) of sediment, gravels or rock
- Recreational structures such as artificial reefs or dive trails
- Military activity

The development of the seabed proceeds apace and will continue to grow. This applies just as much to the nearshore zone as to the deeper waters further offshore. New technologies relating to the underwater zone are under constant development, making the management, and related legislation, of marine activities difficult. Guidelines, and protocols are constantly changing as are the forces that drive them. In some areas, technological development now focuses on parts of the seabed that were once not considered to hold economic potential, such as the high-energy zones of the Pentland Firth. In other areas, the changing economic and technological situation has altered the emphasis or siting of existing industries. Increasing emphasis on recreational marinas now affects many parts of the north and west coasts of Britain, in areas that were once considered 'remote'; new trends in marine commerce have led to the reopening of long forgotten deep-water harbours and routes; offshore anchorages have become a familiar sight in many places. With new technology comes new possibilities, making new demands on the seabed.

It is important to remember that it is not just the activity itself that can be damaging to the archaeology; in many cases the infrastructure associated with an activity may cover more ground and be more damaging than the activity itself. In this way, while the footprint of a marine renewable energy development may be relatively small, and sited on hard rock with no archaeology, the cables and pipes that lead to shore may cross or cut into fragile deposits, and any related structures such as generating houses may sit in archaeologically vulnerable areas within the intertidal or coastal zone. Good management of the marine archaeological resource requires a wide view of development, including the local onshore archaeology.

Good management

In order to ensure the wellbeing of submerged archaeological material, it is necessary to manage the increased development of the seas and oceans and understand the threats that might be posed. In addition, a clear understanding of the resource itself is required (Fig. 8.1). Ongoing research relating to submerged sites and landscapes around the world is not only an academic nicety, it is vital for the survival of the resource. Information from this research can then be incorporated into the management process through direct collaboration and communication, often using a system of environmental impact assessment.

There are many papers and guidelines relating to the management of submerged landscapes and sites around the world. All have different status and many undergo regular re-writing as marine activity, and understanding, proceed apace. Not only does the legislation vary from country to country, but within any one country there will be a variety of material, including: environmental and industrial legislation; industry

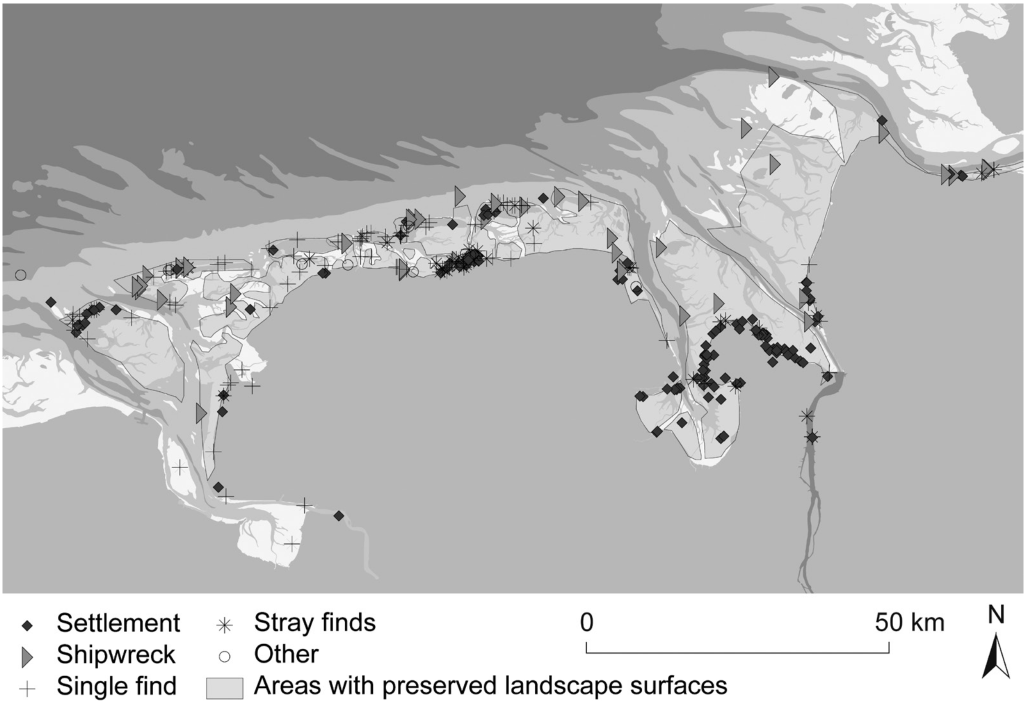


Fig. 8.1 The mapping of archaeological potential, such as here, in the Wadden Sea, Germany, is an important tool for management. Map: J. Goldhammer/M. Karle. Lower Saxony Institute of Historical Coastal Research, Wilhelmshaven, Germany

guidelines; strategic assessments; accords and joint practice documents; professional standards; assessment requirements; and protocols. In addition, the *United Nations Convention on the Law of the Sea* has now been ratified by over 150 countries. It is necessary to remember that seabed management can transcend terrestrial national boundaries.

In general, there is close agreement as to the principles of good practice that should apply to the management of cultural heritage on the seabed such as archaeological sites and the submerged landscapes that give context to those sites. Avoidance, though favoured as an over-riding principle, is not always possible or necessary and the most commonly identified procedures are listed below.

- Seabed archaeology should be treated with equal care to terrestrial archaeology
- Where possible steps should be taken to minimise disturbance to any cultural heritage remains
- Early consultation between developers and resource managers is recommended
- The archaeological heritage should comprise an integral component from the initiation of any development plan whether commercial or otherwise
- Successful management is a balance between preservation and development

- Impact assessment should comprise first a scoping study followed by desk based assessment
- In addition to management of the known resource, investigation, including remote sensing and prospection, should take place to minimise the risk of unexpected discoveries during development
- The acquisition of survey data can be integrated with wider assessment work and, for this reason, a detailed methodology statement on survey techniques should be supplied in advance. This will help to ensure that work is cost effective
- Sampling sites should always be chosen carefully and with reference to the interpretation of pre-existing survey data in order to avoid damage to archaeological remains while maximising the likely success of sampling
- Physical preservation *in situ* is the legally preferred action for significant sites
- Excavation should take place only as a last resort
- The use of watching briefs is particularly important in the intertidal/coastal zone
- The analysis, curation, and publication of finds and information is important
- Ongoing monitoring forms an important part of the management of the cultural heritage resource

The increased awareness of, and respect for, submerged cultural heritage and landscapes around the world means that we are slowly moving from the general benign neglect of submerged sites towards a deeper understanding and active management of the resource. Careful collaboration with industry has led to the emergence of principles of good practice to ensure that this management can take place without prejudicing economic development (Figs 8.2 and 8.3). The choice of procedure is thus dependent on the interplay of information related to the significance and fragility of the archaeological

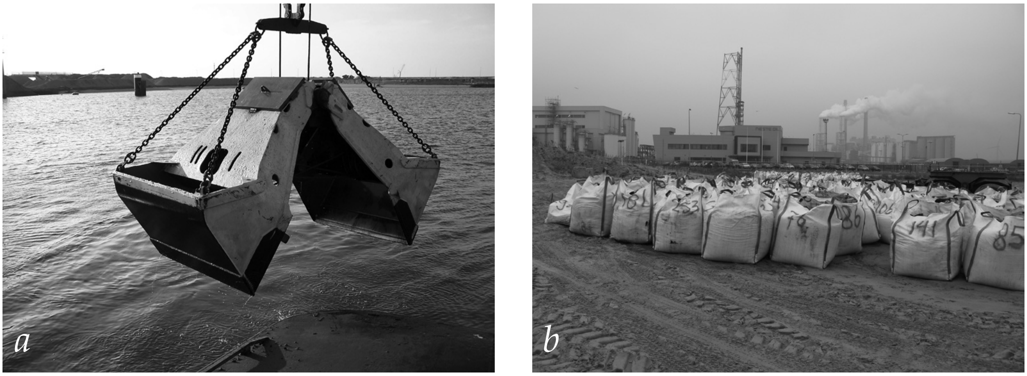


Fig. 8.2 The research undertaken during the extension to Rotterdam Harbour provides an excellent example of the collaboration between archaeology and industry. It included work at Yangtze Harbour to sample material from the seabed twenty metres below and examine it for archaeological finds: a) detail of the sampling device used (normally used for soil decontamination); b) bags of sample material waiting for sorting. Images courtesy of B. I. Smit, Cultural Heritage Agency of The Netherlands

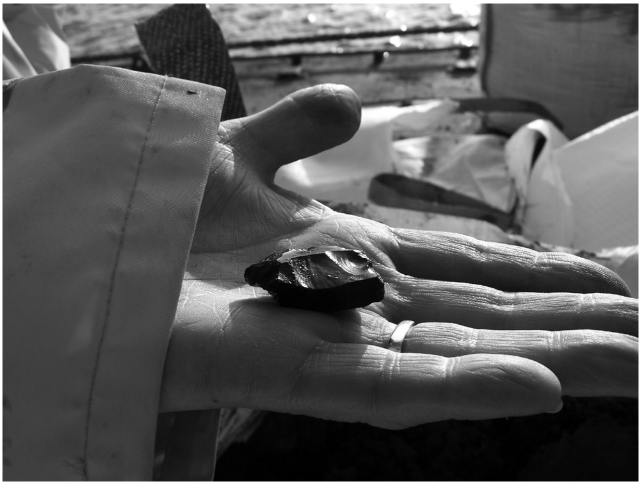


Fig. 8.3 Fragment of worked flint recovered from one of the samples on board the research vessel as part of the archaeological work during the extension to Rotterdam Harbour. Image courtesy of B. I. Smit, Cultural Heritage Agency of The Netherlands

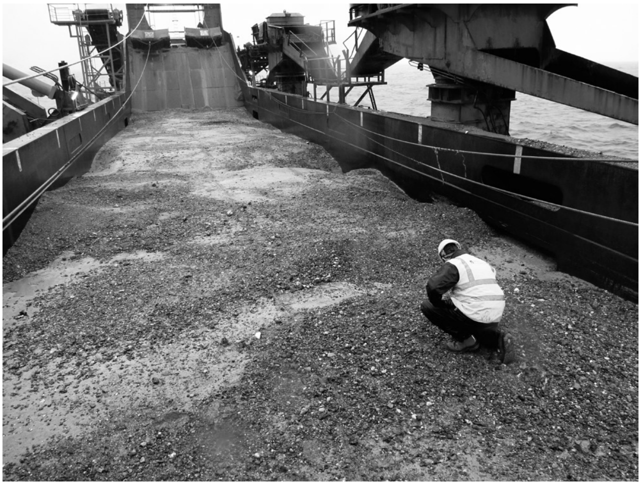


Fig. 8.4 Scanning dredged material at sea during the archaeological research on Area 240. Image: © Wessex Archaeology

resource, vulnerability of the seabed, and the versatility and importance of the development (Fig. 8.4). This information all relies upon the adequate collection of data in advance of the development. In Britain, this takes place during the production of an Environmental Impact Assessment (EIA) as part of the planning process (Wickham-Jones 2010). The detail included within an EIA will rely upon pre-existing knowledge of the submerged archaeological resource in the area in question, and an EIA may, itself, recommend further survey or investigation of the resource prior to development taking place.

UK legislation

The *United Nations Convention on the Law of the Sea* divides the sea into management zones (Fig. 8.5).

- Internal, or Archipelagic, Waters
- The Territorial Zone
- The Contiguous Zone
- The Exclusive Economic Zone
- The High Seas

The Territorial Zone comprises that stretch of the sea which lies from the coast out to 12 nm (nautical miles, 1 nm equals 1.85 km). The Contiguous Zone stretches from the coast for 24 nm and the Exclusive Economic Zone extends to a distance of 200 nm. Beyond that lie the High Seas. As the coast is not a straight line, and often includes island groups, there is also a definition of Archipelagic Waters (sometimes known as Internal Waters) which comprise river estuaries, bays and island sounds.

Within the Territorial Zone a state exercises exclusive sovereignty while within the Contiguous Zone it exercises the sovereignty necessary to protect the territorial waters. This includes claiming the right to protect cultural heritage material on the seabed. The Exclusive Economic Zone exists to protect the rights of the state over the resources within that zone, including both extraction and conservation. With regard to archaeological research, it is worth noting that the term Contiguous Zone has come to be used to cover palaeolandscapes, and thus the potential submerged archaeological resources, that extend as far as the edge of the continental shelf.

In the UK, the management of the sea is divided between the UK and individual national governments. Overall, a system of marine licensing was introduced by the *Marine and Coastal Access Act 2009* which covers offshore waters out to the edge of the Exclusive Economic Zone. This established an independent Marine Management Organisation to oversee protection of the marine environment. Territorial waters, however, are the responsibility of the individual UK Administrations (advised by the relevant heritage body). In Scotland, the *Marine (Scotland) Act 2010* allocates power over the waters out to the edge of the Exclusive Economic Zone to the Scottish government.

These Acts acknowledge a wide variety of cultural remains and outline the intention that submerged archaeology should be respected and carefully managed alongside other environmental resources. With this intent, provision is made for various measures to manage the seabed through a system of licensing and evaluation. Across the UK the policy behind marine planning and licensing decisions has been set out in the UK Marine Policy Statement (HM Government, 2011). There are clear lists of ‘licensable marine

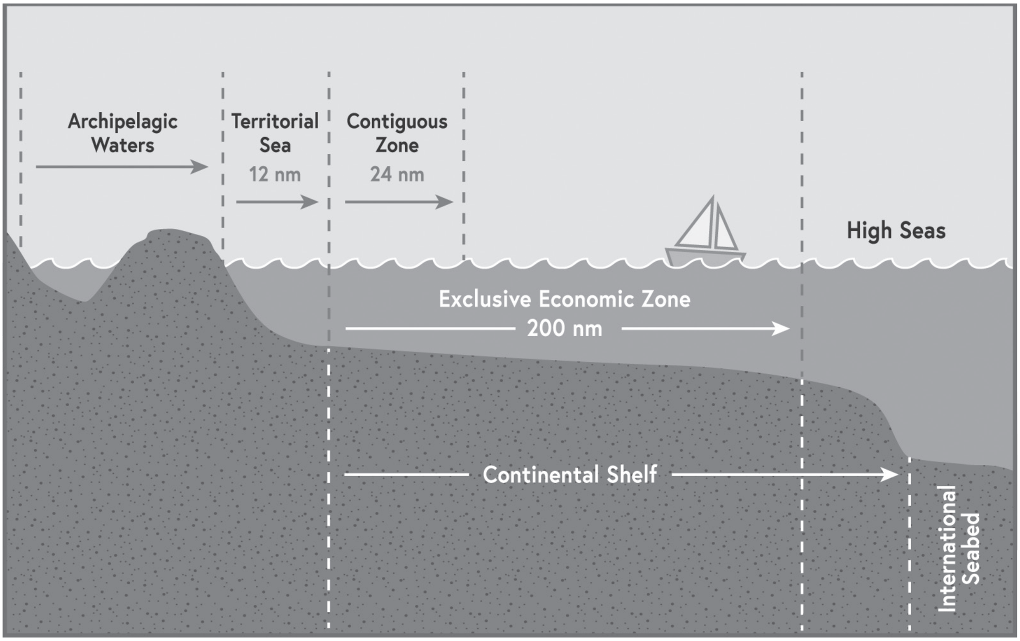


Fig. 8.5 United Nations Convention on the Law of the Sea: Management Zones. NB: Archipelagic Waters can include bays and river estuaries; sovereignty rights out to the far edge of the Continental Shelf cover the natural resources of sea, seabed and subsoil. With regard to archaeological research the term Contiguous Zone is used to cover palaeolandscapes that extend to the edge of the continental shelf. Measurements in nautical miles (1 nm = 1.85 km). Image: Rhona Jenkins

activities' (MMO 2014) and the Marine Management Organisation takes advice from the relevant Administration as to the possible cultural heritage significance of activities. In Scotland, the *Marine (Scotland) Act 2010* provides an added layer of protection in the form of Historic Marine Protected Areas which can include shipwreck sites as well as submerged archaeological sites and landscapes. Elsewhere in the UK, the *Protection of Wrecks Act 1973* operates alongside the traditional scheduling and listing of remains under the *Ancient Monuments and Archaeological Areas Act 1979*. In addition, military remains around the UK are protected under the *Military Remains Act 1986*. Although the protection and management of archaeological resources comes mainly under national legislation, there has, as yet, been little consideration of the possible impact on marine conservation once Britain leaves the European Union.

A significant impact of these acts has been to see the widening of the definition of 'marine historic asset' to include a 'deposit or artefact (whether or not formerly part of a cargo of a ship) or any other thing or group of things which evidence previous human activity'. The intention is to cover sites that may only be represented as artefact scatters. The recovery of artefacts has to be authorised and should be reported. The Acts also specifically cover palaeoenvironmental deposits and features relating to submerged landscapes (for example submerged peat deposits or forest remains) not only for their natural value, but for the potential evidence of human impacts that they may contain.

In general, this legislation is designed to work in a streamlined and complementary way around the UK, and operates on five principles:

- Planning;
- Licensing;
- Research;
- Conservation;
- Enforcement.

This legislation is not intended to reduce public access, for example though diving, to submerged sites and landscapes, and it is not intended to reduce research.

While the UK legislation is relatively new, and research on the submerged landscape is still in its infancy, there have been a number of designations in Scotland which indicate the success of the system (HES 2015; 2016). These include seven Marine Protected Areas, seven vessels protected under the *Protection of Military Remains Act 1986*, and seven Controlled Sites also designated under the *Protection of Military Remains Act 1986*. Ongoing research will inform new management and protection. With this in mind, all of the national Heritage Agencies (Historic England, Historic Environment Scotland, CADW, Historic Environment Northern Ireland) operate programmes on themes such as coastal archaeology, the analysis of erosion and its impact on archaeology, and marine archaeology. In addition to independent research, programmes like these serve to enhance the implementation of the legislation and can vary considerably over time. It is always a good idea to contact an agency to find out about current themes.

Outside Scotland, the *Ancient Monuments and Archaeological Areas Act 1979* (AMAA 1979) provides the power to protect sites within the UK Territorial Seas by scheduling them as monuments. In practice, its power at sea has been limited not least because it was designed to protect structural remains rather than deposits of artefacts. The *Protection of Wrecks Act 1973* is designed to protect wrecks and the sites of wrecks by the definition of an area within which lies the best-known location of a wreck. Section One 'provides protection for designated wrecks which are deemed to be important by virtue of their historical, archaeological or artistic value' while Section Two concerns the management of wrecks that are deemed to be dangerous. The *Protection of Military Remains Act 1986* protects vessels and aircraft that are military maritime graves. Operation of this Act has been reserved for the UK Government; it is managed by the Ministry of Defence. Sixteen vessels within UK jurisdiction are designated as Controlled Sites, and five vessels in international waters as Protected Places. Protection is not primarily archaeological, but the MoD liaises closely with the relevant agencies over the process of site designation.

While legislation with regard to UK waters is relatively recent, a number of older international conventions also cover underwater archaeology and their provisions should be borne in mind. The *United Nations Convention on the Law of the Sea* (UNCLOS) was agreed in 1982 and ratified by the UK in 1997. Article 303 (1) of UNCLOS stipulates that all states have the duty and right to protect archaeological resources found at sea 'and shall co-operate for this purpose'. The *UNESCO Convention on the Protection of the Underwater Cultural Heritage* (UCPUCH) (General Conference, 31C, 2001) was adopted in 2001, but has yet (August 2018) to be ratified by the UK. It develops the powers relating to protection for 'objects of an archaeological and historical nature' codified within UNCLOS. The Convention is generally recognised as an important way forward for the protection of underwater cultural heritage, and the UK government (and other governments) has been urged to re-consider its position regarding ratification (Gonzalez *et al.* 2009).

The *European Convention on the Protection of the Archaeological Heritage* (Revised) (*The Valletta Convention*) was launched in 1992. It was ratified by the UK in 2000 and came into force here in 2001. Although derived from archaeology on land, the convention does apply 'underwater' (Article 1.3 and 2.ii). Its provisions are wide-ranging and cover matters such as the identification and registration of sites, licensing and standards for operations, the prevention of looting, and the control of the antiquities trade. There has been some debate as to whether *The Valletta Convention* applies outside of territorial waters, but the normal position with international instruments is that they apply only so far as the relevant national legislation provides jurisdiction.

The Valletta Convention (VC) is designed to operate through the existing legislative framework of individual signatories (English Heritage 2001), whether in relation to heritage, or to planning and the control of pollution, where these have the potential to impact on the archaeological heritage. In common with many articles of UNCLOS which relate to scientific research, it links the cultural heritage with the concept of 'historical and scientific study' (Article 1.1) and 'research into mankind and the related environment' (Article 1.2.i). It also provides for 'archaeological reserves' on land or under water (Article 2) and outlines the consultation which should take place between planning authorities and developers in order to avoid damaging archaeological remains (Article 5). It has, in the past, been called into evidence in UK proceedings such as Public Local Inquiries, for the light it sheds on international standards and best practice. While the existing UK legislation has been designed to be straightforward and practical in implementation, and is thus mainly concerned with management, when it is combined with the international conventions a powerful suite of recommendations is created which integrates protection and management together with research, understanding and access.

Industry protocols and guidelines in the UK

In addition to the legislation, government agencies, heritage organisations, planning authorities and industry representatives have worked together to develop non-statutory protocols and codes of practice for the protection and management of offshore cultural heritage. Although written with many different types of development in mind, the principles established in these documents are based on years of experience and provide sound guidance. As they are frequently revised and updated it is not possible to list them in a useful way, but it does not take long to locate them via an internet search engine.

Other, more general, offshore guidelines such as those produced for the offshore renewable energy sector, COWRIE (Wessex Archaeology 2007), also advocate consideration of the historic environment. Although in practice this does mean that archaeology is (or should be) included in routine Environmental Impact Assessment work, it is worth noting that a lack of appropriate archaeological knowledge relating to past relative sea-level change and the submerged cultural heritage among those responsible for the EIA can, all too often, relegate cultural heritage to a few inappropriate sentences (Wickham-Jones 2010). It can also lead to the misjudgement of the implications of the impact of development on the archaeological resource and submerged landscape. The assessment of the potential significance of any submerged cultural material is a specialised business, requiring access to detailed research data. Quinn (2004) stresses the importance of archaeological competence in both the supply and interpretation of data but in practice this is not always forthcoming.

Environmental Impact Assessment (EIA)

The production of Environmental Impact Assessments (EIA) that incorporate archaeology (whether submerged or on land) is central to the good management of the cultural heritage across and around the UK. Environmental Impact Assessments have been refined through years of practice relating to sites on land and, more recently, underwater (both at sea and in freshwater conditions). Planning practice on land requires the assessment of any likely impact of the development or works on the cultural heritage resource and this is undertaken as part of the Environmental Impact Assessment. This assessment is then presented together with that for other resources. Environmental Impact Assessments were developed as part of the planning process, required by European Union Directives (EC Directives 85/337, 85/883, and 97/11/EC). In the long term, after Britain has left the European Union, it is assumed that comparative measures will be put into place to maintain the system.

EC 85/883 covers archaeology under the heading of ‘cultural heritage’. EC directives 85/337 and 97/11/EC cover coastal development and include archaeology and architectural heritage as an integral component. The procedure relating to the production of Environmental Impact Assessments is enshrined in the Town and Country Planning (Environmental Impact Assessment) Regulations which have numerous amendments to ensure appropriate coverage across the individual UK Authorities. They require developers to produce a statement of the likely impact of the proposed work upon the environment which is defined very broadly to comprise a number of specified biophysical, social and other resources. Mitigation measures should also be considered and noted in the EIA, together, if relevant, with an assessment of alternative plans. This statement is then circulated to statutory consultees, and to the public, for comment before it, and the comments, are all considered by the planning authority as part of the process of consent, before any decision is made as to whether or not the development should go ahead. While there is a presumption that any active community requires economic development in order to survive, the idea behind this planning process is to mitigate against the unplanned and steady erosion of the environmental setting and resources of an area.

With regard to archaeology on the seabed, the success of the whole Environmental Impact Assessment process is obviously dependent on the recognition by all parties that submerged terrestrial sites and landscapes comprise a resource worthy of consideration. While wreck sites are well established within EIA practice, the submerged terrestrial resource is a newer field and may still be overlooked or dealt with summarily. In general, crucial roles are played by the developer, the curator (usually the relevant regional or local authority archaeologist), and the contractor (the company responsible for compilation of the EIA report) who may, or may not, hold the requisite specialised archaeological knowledge. The UK legislation of 2009 and Scottish Act of 2010 now operate a system of licensing for marine activities, and the production of an EIA is still an important part of the process. Where designated resources are concerned, such as sites within a Marine Protected Area, or protected wreck sites, the national heritage agency (Historic England, Historic Environment Scotland, CADW, Historic Environment Northern Ireland), takes on the role of consultation authority (curator) though they may also refer developers to the local authority archaeology services especially in cases where the development concerns coastal or intertidal work. Some developments, such as fish farming, are indeed reserved for the jurisdiction of the local or regional authority. At present, considerable onus is placed on the local or regional archaeologist to recognise situations where submerged terrestrial sites might be relevant. This is a difficult task, especially given their lack of specialised training in the field and the general lack of awareness and information relating to the resource. Where relevant, Scheduled Monument or Listed Building Consent for developments on land, and sectoral consents (e.g. section 36 consents under the *Electricity Act 1989*) also have to be incorporated into this planning process.

In practice, most developers contract a company to produce the Environmental Impact Assessment. The specialised environmental groups who do this may, or may not, incorporate in-house expertise in archaeology whether on land or at sea, and many will bring in an outside archaeological consultant or company. It may also be the case that specialised archaeological information is not relevant for the EIA, which may, therefore, include little archaeological detail. In practice, responsibility for deciding whether, or not, to include archaeology is not always clear cut, and, ironically, the submerged resource can suffer in areas where the potential for submerged sites and landscapes has not already been investigated. It is also pertinent to note that the lack of relevant expertise on the part of most environmental companies and developers can make it difficult for them to judge the quality and local relevance of the archaeological information incorporated within the EIA and the implications of the mitigation measures recommended.

Production of an Environmental Impact Assessment is also required of public bodies, including the government, with regard to the possible impacts of most of their plans, programmes and strategies. These assessments are known as Strategic Environmental Assessments (SEAs) and are required by UK law through the European Strategic Environmental Assessment Directives and their amendments. In practice, many departments begin the SEA process at an early stage. While the coverage of a SEA is more general than that of an EIA, they are also important documents which have a bearing on both individual practice and on the contents of subsequent EIAs. A good example of relevant SEA documents relates to the reports published online by the UK Department of Trade and Industry who, in 1999, started the process of compiling SEAs with regard to the implications of licensing of the UK continental shelf (UKCS) for oil and gas exploration and production. The UKCS was divided into eight zones and SEA documents relating to all of them have now been published online (http://www.offshore-sea.org.uk/site/scripts/sea_archive.php). Where relevant, prehistoric archaeology was considered as a separate resource, and often given a separate document.

Awareness, public access and interpretation

Shipwrecks have long held a fascination for the public. They are often seen as romantic, despite the inevitable tragedy of their creation. Museums such as that of the *Mary Rose* in Portsmouth, England, or the *Vasa*, in Stockholm, Sweden, are popular tourist destinations that make the most of the intimate snapshots of time provided by the remains. Moving from the popularity of shipwrecks to the more prosaic remains of submerged sites and landscapes has been difficult, though some sites, such as the sunken harbour of Alexandria in Egypt, retain a visual fascination that can be appreciated by the non-diving public. General awareness of lost landscapes, such as Doggerland or Beringia, is only just underway.

Despite the issues inherent in interpreting and presenting archaeology that may not be very visual, nor easy to access, it is important to do so. Increased public awareness introduces increased interest in the preservation of the resource and in this way successful management, including the preservation of significant remains, is facilitated. Increased general awareness facilitates the successful implementation of the legislation.

With regard to terrestrial sites, the easiest way for people to experience them is by direct access. Direct access is, however, much more difficult underwater and requires a certain level of skill and competence. Nevertheless, in many parts of the world, dive trails have been developed to help divers visit and understand sites. The underwater archaeological park of Baiae, in Italy, is promoted primarily for divers. Elsewhere, local systems of diving, including the hire of diveboats or guides, work well for visitor and local alike. Most people, however, do not dive, meaning that remote access has become more important. This may take the form of carefully controlled dive experiences using fixed air supplies, glass bottomed boats, or remote operated cameras and on-board screens, but it can also include websites, three-dimensional reconstructions and virtual reality. Books and television provide significant sources of information, but diving is essentially an immersive experience, one for which new applications of computer gaming and three-dimensional visualisation are particularly useful.

9. Submerged landscapes around the world: Asia, Africa and the Americas

North America

The availability of new technology and increasing awareness of the potential of the resource, has led to various submerged landscape projects around the coasts of North America. Studies have taken place from California, where the Santarosae project makes an excellent example of integrated survey and diving work to investigate the ancient landscape and its inhabitation (Watts *et al.* 2012), to Florida where information on submerged landscapes and their possible archaeology is built into the Cultural Resource Management systems (Faught 2014a). Guisick and Faught provide a good summary with many references to projects around the coasts of North America and their significance (2011). Yet, Faught (2014a) also notes the patchy protection and lack of active management often associated with the discipline in the USA.

Around the continent two areas stand out, partly because of their longer history and the active nature of research there, and partly because of the very nature of the resource in these locations: Beringia and Atlantic Canada from Newfoundland to Nova Scotia. Counter-intuitively, both areas offer what might be conceived of as difficult environments for underwater research, given their high latitude locations and often high energy waters. Work in these two areas highlights how approaches may be tailored to areas of known potential, yet difficult access. While research in Beringia focusses more on the theoretical analysis of earlier landscapes and their potential for human migration and settlement, in Atlantic Canada individual projects incorporating a variety of different approaches have been used to build a greater whole. Both areas provide good examples of the value and future potential of this type of research.

Beringia

Beringia comprises an area of land and water, defined today by the Mackenzie River in Canada and the Lena River in Russia and extending from 72° north to the tip of Kamchatka (US Park Service 2013). Within this area lie the narrow Bering Straits, part of the continental shelf (Fig. 9.1). The archaeology of Beringia includes terrestrial sites as well as the submerged landscape.

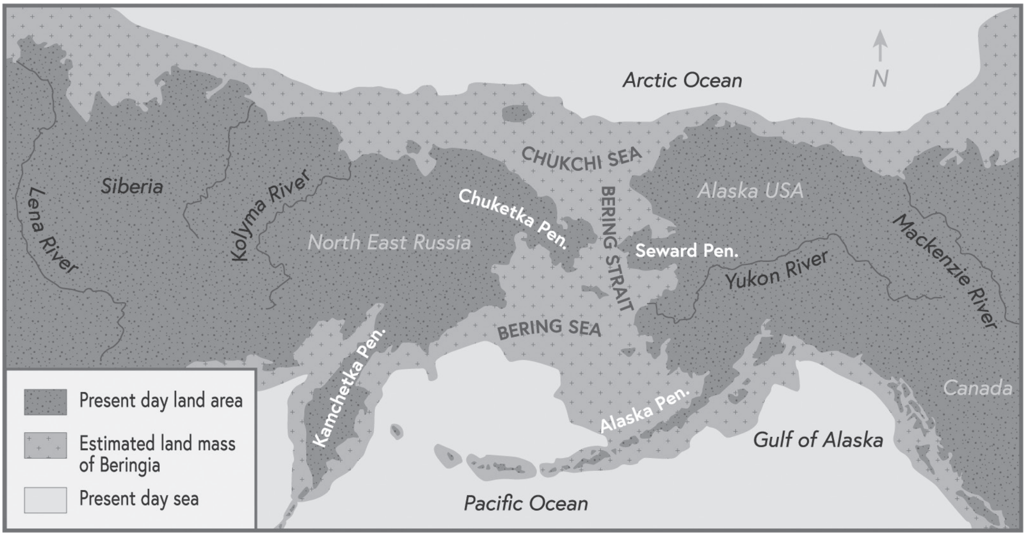

Arctic Ocean
N
CHUKCHI SEA
Siberia
Lena River
Kolyma River
North East Russia
Chuketka Pen.
BERING STRAIT
Alaska USA
Seward Pen.
Yukon River
Mackenzie River
BERING SEA
Kamchetka Pen.
Alaska Pen.
Canada
Gulf of Alaska
Pacific Ocean
Present day land area
Estimated land mass of Beringia
Present day sea

Fig. 9.1 The landmass of Beringia. Image: Rhona Jenkins

Beringia is a significant location for the study of submerged landscapes, not least because of the way in which the terrestrial and underwater archaeology are regarded as part of a unified whole. This approach has, largely, yet to be achieved in studies closer to home; for example, research on Doggerland still focuses on a submerged landscape that is defined by the UK and European coastlines to either side of it. Whereas Doggerland is expressed as an underwater landscape that operated in conjunction with the adjoining landmasses, the archaeology of Beringia comprises an environmental and cultural landscape that stretches across both dry and inundated terrain as a seamless whole, and this produces a more holistic view.

First ideas relating to the possibility that the relatively shallow waters between North America and Asia might once have joined the two continents were published by the Spanish explorer and missionary Brother José de Acosta in 1604 but only really developed from the late nineteenth century onwards (Dixon and Monteleone 2014). The name Beringia was coined in the 1930s. It is a significant area. Understanding of the past environment, topography and archaeological history of Beringia is key to understanding of the first peopling of the Americas because it is across Beringia that the earliest human colonisers are likely to have travelled. Nevertheless, the technical issues relating to underwater survey in such high latitudes have confined work to the land until recent decades.

There are two models of colonisation into North America: an interior route across the interior of Beringia and then southwards avoiding the continental ice sheet from 13,000 cal BP onwards; or a coastal route using sea transport and island hopping to continue south along the Northwest coast which would have been ice free from about 16,000 cal BP. Despite ongoing research and discussion, the evidence is still equivocal, and, not surprisingly, actual events are likely to have involved the conflation of the two. Recent research including both archaeological and aDNA evidence suggests that Beringia may have provided a home for pioneering communities en route towards the east for several millennia perhaps from as early as 20,000 years ago (Hoffecker *et al.* 2014; Tamm *et al.* 2007). Llamas and colleagues use information derived from the study of ancient mitochondrial DNA to discuss the separation of communities from the populations of Siberia some 25,000 years ago and their subsequent isolation in eastern Beringia before the melting of the ice sheets that allowed them to move south into mainland north America around 16,000 years ago (Llamas *et al.* 2016). In general, the importance of the coastal landscape of Beringia in facilitating this movement south through the provision of resources and transport for the communities who lived there from an early date is regarded as increasingly significant (Erlandson *et al.* 2007). This applies to both the submerged coasts of the Beringian continental shelf which are relatively inaccessible today, and the submerged coasts of the Northwest coast of North America, where new technologies are facilitating investigation for early sites.

On land, there are many archaeological sites on either side of the Bering Sea and along the Northwest coast of North America that relate to the early occupation of Beringia, though underwater sites have been harder to find (Dixon and Monteleone 2014). Despite the chance discoveries of possible sites none has been verified, and there have been few targeted projects, of which only one has come up with a (single) stone artefact (Fedje and Josenhans 2000). Ongoing research is using high definition survey work to investigate the submerged ancient landscape along the northwest coast and target possible hunter-gatherer sites identified by predictive modelling (Dixon and Monteleone 2014). To date this research has located at least one possible site and examined various artefact locations, though no certain finds have been confirmed. Positive results have been confirmed from recent investigation of the shoreline, however, with the publication by McLaren and colleagues of research on Calvert Island, British Columbia (McLaren *et al.* 2018). Using a detailed understanding of shoreline change in the area the team were able to target the location of exploratory trenches in the intertidal zone searching for possible archaeological and palaeoenvironmental material. This resulted in the excavation of 28 human footprints together with a small lithic assemblage. The deposits are dated to between 13,300–13,000 BP, providing the earliest evidence, to date, for human occupation of this coastal zone. It is a wonderful example of the possible rewards of exploratory research.

Other research is investigating the past topography and palaeoenvironment of Beringia including the rates and processes of deglaciation and marine inundation. There have been finds of Pleistocene fauna, such as mammoth, from the seabed (Dixon 1983) and with increased awareness it is to be hoped that more archaeological material will be discovered and reported.

Atlantic Canada

Atlantic Canada comprises the waters from Newfoundland to the east, into the Gulf of St Lawrence and over to Nova Scotia to the west. Research into the submerged landscape here has only been active in recent decades (Lacroix *et al.* 2014), but the history of Holocene relative sea-level change and topographical evolution means that there is considerable potential. While the area was almost entirely under ice during the Last Glacial Maximum, the history of deglaciation was complex with the result that the ancient landscapes of the northern coastlines all lie above water while in the southern half of the region there are extensive tracts of submerged landscape (Pl. 28). This has created a landscape in which large offshore islands played an important role for the early inhabitants. In some places there was an early history of emergent landscapes, but overall gradual submergence has been an ongoing process from around 11,000 BP. Many of the original southern island groups now survive merely as offshore banks, subject to considerable marine erosion.

The earliest inhabitants of the area are recorded in hunter-gatherer sites dating to around 8500 BP (McGhee and Tuck 1975). In the south, the sites are dated slightly later, due to an acknowledged coastal bias of human activity here, so that sites are only found once the coast reaches its present position, earlier sites must lie underwater (Tuck 1975). The history of relative sea-level change in Atlantic Canada means that while the archaeology does include both terrestrial and submerged landscapes, extensive tracts of territory are now inundated, including whole offshore island groups.

Interestingly, and for obvious environmental reasons related to storminess and the fragility of the resource, research into the submerged landscapes in this area has been combined with a strong management aspect. This is not only designed to identify potentially fragile sites and landscapes that will be vulnerable to the onset of Atlantic gales and storms, but also to assist in the recognition of surviving material. In many areas, high energy waters or the offshore location of original island landscapes reduce the likelihood that archaeology will have been preserved, but elsewhere there are sheltered locations deemed to be of archaeological potential. These include features of the submerged landscape such as fossil estuaries or valleys, or even submerged caves and rockshelters, as well as locations within the present coastal zone such as the lee of present islands.

Finds related to early settlement of the submerged landscapes of the region to date comprise material that has been brought to the surface by divers or fishing boats. As such the locations relate mainly to present day fishing grounds and recreational areas such as the Gulf of Maine and the coastal waters of Newfoundland (Lacroix *et al.* 2014). In some areas high resolution remote sensing, including multibeam survey of the seabed has been able to reconstruct the submerged landscape in a way that offers considerable potential for the future investigation of early human activity (Shaw 2005). A multi-disciplinary study combining remote sensing, palaeoenvironmental work, ethnographic information relating to seal hunting and artefact analysis around the Magdalen Islands has highlighted the likely existence of extensive seal-hunting grounds around the islands in the Early Holocene, enabling reinterpretation of finds of harpoon assemblages from existing terrestrial sites to the Late Archaic period *c.* 6000–4000 BP by which time the coast approximated its present position (Lacroix *et al.* 2014). While evidence has yet to be found for the postulated earlier, Late Palaeoindian, communities who exploited the extended hunting grounds around the islands during periods of lower relative sea-level, a palaeogeographic study such as this is of considerable use in building an understanding of the early settlement of the area and furthering research into the submerged landscape.

Another targeted study has focussed on the northeast coasts of Newfoundland and combined information from sea-level reconstructions, remote sensing, core sampling, and modelling in order to build a picture of the submerged landscape at various time slices, and test it for archaeological potential (Westley *et al.* 2011). This resulted in a detailed reconstruction of the submerged landscape and the process by which it flooded. Archaeological testing was restricted to work in the intertidal zone, but resulted in the recovery of several concentrations of stone tools which highlight the potential of the area.

One other facet of the work in Atlantic Canada has been the ethnoarchaeological work undertaken to investigate links between folk history and natural events. The Bay of Fundy is known for the great height of its tidal regime which has been developing since the Early Holocene (Shaw *et al.* 2010). The Minas Basin lies at the southeastern end of the Bay, separated from it by a narrow channel, through which the tides flow. The archaeological record of this area is strong and includes some of the oldest Palaeoindian sites to be recorded in Atlantic Canada. Local peoples include communities of the Mi′kmaq and Ojibway tribes who trace their ancestry back within the area. A local Mi′kmaq story recounts how the Minas Basin was linked to the Bay of Fundy and its tides (Rand 1850). The story relates how Glooscap, a man-god, seeking to create a bathing place for himself, angered Whale who then broke through Glooscap's dam and, in thrashing his tale around, created the tides. Shaw and his colleagues relate this tale very precisely to the sudden breaching of the natural barrier at the mouth of the Minas Basin, around 3400 BP, resulting in the ingress of the tidal waters (2010).

The extensive submerged landscapes of Atlantic Canada offer considerable challenges for archaeological investigation. It is, nevertheless, an area in which initial work highlights the great potential and rewards to be derived from interdisciplinary projects including geoscience, archaeology and ethnographic work.

The freshwater landscape beneath Lake Huron

The massive freshwater bodies of North America also conceal submerged landscapes with considerable archaeological potential. Research below Lake Huron by a team from the University of Michigan has revealed considerable detail of the landscape as it would have been between 11,500 and 7000 years ago, when water levels were as much as 100 m lower (O'Shea *et al.* 2014). The investigations include both palaeoenvironmental work and archaeology and they provide a fascinating picture of the activities of the caribou hunters who occupied this area for periods during this time (Pls 26, 27 and 30). Over 60 stone structures, including hunting drives and traps and domestic sites have been recorded at depths between 30–40 m of water, by various types of acoustic survey and ROV examination, and selected remains were then surveyed by scuba divers. In a few locations, further work included the recovery of lithic artefacts. The research team notes that the terrestrial archaeology of the area for this period is poorly understood with the result that the information from the underwater project provides a significant enhancement to interpretation of the lifeways of the prehistoric communities who lived to the south of the Laurentide Ice Sheet in its final millennia.

Central America and the Caribbean

Many of the projects around the coasts of Central America and in the Caribbean are coastal in nature, relating to inundated sites that lie in close proximity to the present coast, for example work on the Mayan sites of Quintana Roo, Mexico which combines field survey in mangrove swamps, and the intertidal zone, with terrestrial archaeology (Glover *et al.* 2012). Most of these sites relate to the maritime aspects of an essentially terrestrial population. Elsewhere, however, investigation has identified both landscapes and the sites that once occupied them, especially off the coasts of Florida and in the Gulf of Mexico.

General awareness of human activity on the seabed around Florida dates back at least to the late 1960s with the recognition of stone tools and shell midden material taken from within dredging deposits removed from Tampa Bay (Goodyear and Warren 1972; Goodyear *et al.* 1983). This is an interesting early example of the investigation of a submerged landscape where commercial underwater activities led to the recovery of archaeological material. Other archaeology projects have made use of material identified by recreational divers and, in addition, there has been considerable research on the submerged landscape, both at a local level (Faught and Guisick 2011) and across the wider region. In the 1980s and 1990s Faught made use of high resolution bathymetry and geological information to reconstruct the submerged landscape and possible human activity in the Big Bend area of Florida and the Gulf of Mexico (Faught 1996; 2014b). He then tested his conclusions about site location using targeted remote sensing and scuba dives and this resulted in the location of thirty-six submerged sites with cultural material, including over four thousand stone tools (Fig. 9.2), animal bone deposits and environmental material. This work has extended understanding of the early occupation of Florida within its original landscape setting.

Similar work, making use of up-to-date technology, was then undertaken by Duggins across a slightly wider area. Duggins' PhD research made use of existing survey data to reconstruct the submerged landscape using GIS models to which he then applied predictive modelling using data drawn from terrestrial Palaeoindian sites in Florida. In this way, he aimed to assess the suitability of the submerged landscape for human activity and to evaluate the likelihood that archaeological sites might survive. Aside from his positive assessment of the submerged landscape, Duggins' research is interesting for the way in which he reminds us that the submerged cultural record is not only about coastal sites: he emphasises the considerable potential of submerged palaeochannels and riverine locations. Duggins did not go on to test any of his potential locations (Duggins 2012).

On the Pacific coasts of this region, research into the submerged landscape is considered key, not only to a full understanding of early human settlement activities, but also as an extension of information relating to the migration and spread of population across the Americas. Investigation of the island of Espiritu Santo, off the east coast of Baja California, has resulted in the creation of digital terrain models for the submerged landscape, using bathymetry of the seabed to give a proxy for the ancient topography (Gusick and Davis 2010). This was combined with predictive modelling relating to hunter-gatherer settlement in the area, in order to target possible locations for archaeological sites which could then be narrowed down by applying information

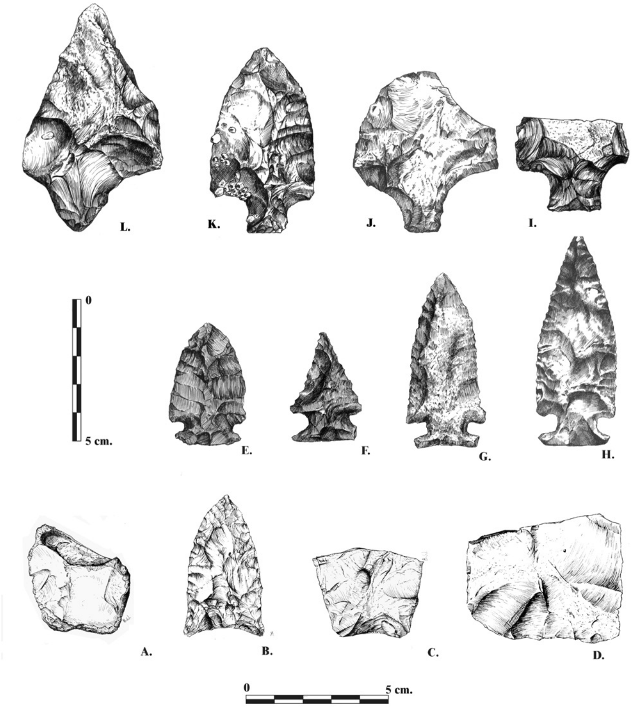


Fig. 9.2 Key types of stone point from the Palaeo-Aucilla River research in the Big Bend area off the northwest coast of Florida. A–D) Palaeoindian points including probable fluted points; E–H) Early Archaic points; L–I) Middle Archaic points. Image: M. Faught, from Faught and Gusick (2011)

related to likely site preservation. Underwater surveys, using scuba divers, were used to assess individual locations. The final stage of fieldwork here involved the digging of test pits on the seabed. Although possible shell midden material was located at one of the sites, it was impossible to verify whether the potential stone finds had been flaked, due to rolling and erosion.

In addition to the submerged landscapes of the Early Holocene, it is worth reminding ourselves of the contribution of more recent sites, of which the submerged city of Port Royal, at the entrance to Kingston harbour in Jamaica, is an excellent example. Submerged very rapidly as a consequence of an earthquake in 1692, underwater excavation since the mid-20th century (Hamilton 1984) has revealed just how well preserved many of the remains are, including buildings, streets and ships from all of which an extensive range of artefacts has been recovered (Pawson and Buisseret 2000). These artefacts reveal a picture of a flourishing, widely-connected, and vibrant city which was, apparently, referred to at the time as 'the wickedest city on earth'. More recent investigation here has included underwater survey and three-dimensional mapping in order to assess the condition of the *in situ* material.

South America

Despite the extension of the continental shelf around South America, there has been very little research on the submerged landscape here. Early habitation by groups of coastal hunter-gatherers indicate that there is considerable potential for archaeological remains, but work to date has been focussed on intertidal and nearshore sites.

The site of La Olla in Argentina, on the Atlantic coast, lies at the edge of the intertidal zone and has been known since the early 1980s. It is usually covered by the tide, and only appears infrequently which has made targeted excavation difficult (Bayón and Politis 2014). Work in 2008 was able to provide a more detailed context for material recovered on previous occasions. The site, which has been dated to 8300–7600 BP, is remarkably well preserved and finds included stone tools as well as worked bone and wood and an extensive collection of environmental material including shells, animal bone, and plant remains (Blasi *et al.* 2013). At the nearby site of Monte Hermoso I, related sediments have preserved considerable stretches of human footprints dating to the same period (Fig. 9.3) (Bayón and Politis 1996).

On the Pacific coast, in Chile, the site of GNL Quintero 1 lies in the nearshore zone, some 13 m underwater. The site was discovered by targeted diver survey related to investigations into the potential archaeological resource in an active harbour area (Carabias *et al.* 2014). Work included sediment coring and excavation through the use of a water dredge. No artefacts were recovered but the extensive assemblage of animal bone is a significant reminder of the favourable preservation conditions and archaeological potential of locations like this. This location has been dated to around 13,000 BP by dating the sediments and research into the palaeolandscape development is ongoing.

The lack of research into the submerged landscapes of South America may seem daunting, but it also presents an excellent opportunity. Knowledge related to the submerged landscape to date is largely based on the opening up of relevant technology and as the technology advances, so does the potential of the discipline. Work on land is developing a detailed understanding of the coastal hunter-gatherers who exploited the resources of the seas around South America (e.g. Orquera and Piana 2009), and sites such as those cited hint at the antiquity and complexity of this relationship when sea-levels were lower.

Australia and New Zealand

In common with South America, the submerged archaeology of New Zealand is largely undeveloped, though inundated sites and resources do exist (Carter and Dodd 2015). New Zealand is surrounded by an extensive continental shelf area, though much of it is too deep to be of relevance with regard to ancient sites. Nevertheless, the inshore area is worthy of attention and at least one freshwater site, inundated due to seismic instabilities has been recorded (Grace 1982), but research on underwater archaeology to date focusses on shipwrecks.

Research in Australia has to contend with various obstacles, not least the fragile and ephemeral nature of sites, exposure to storms and other erosive forces along

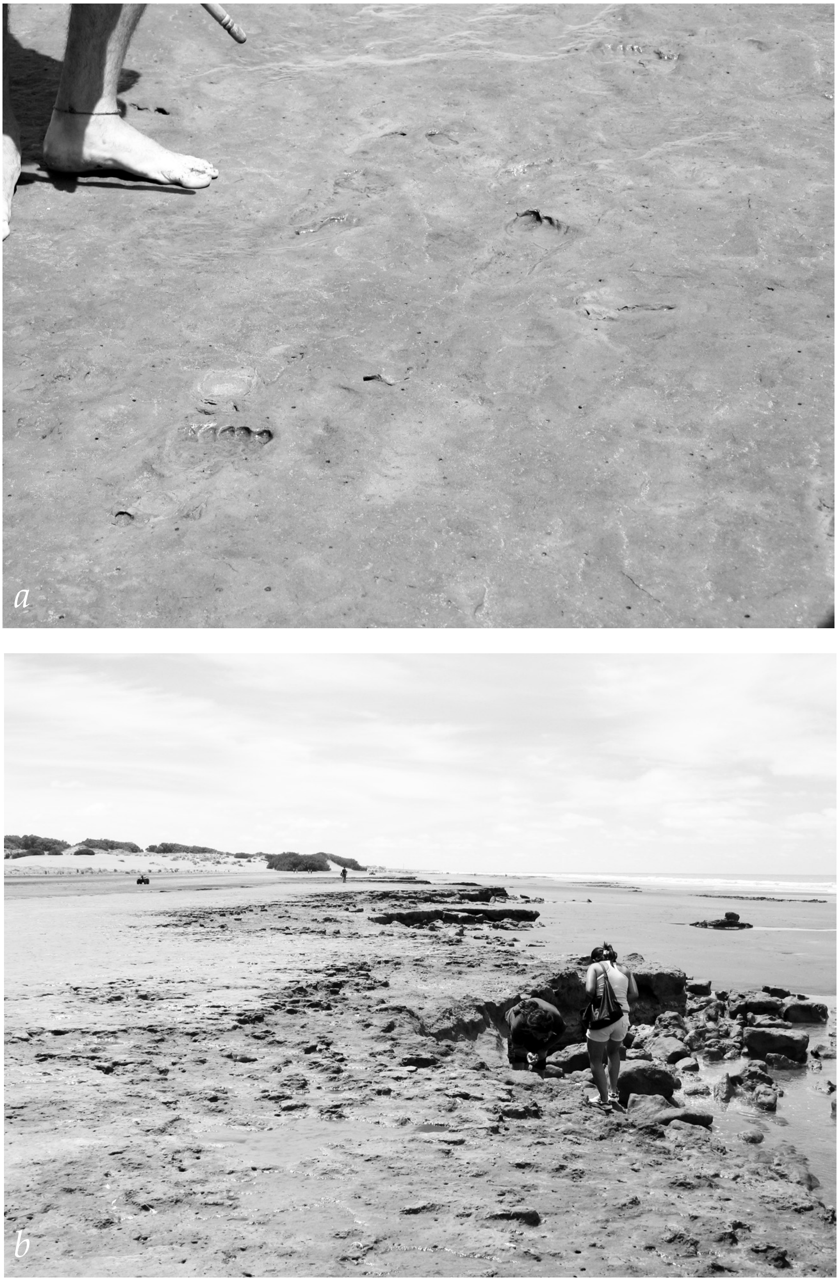


Fig. 9.3 a) Prehistoric footprints in the beach sediments at Monte Hermoso, Argentina; b) the location of the footprints, preserved in slightly more robust material, is still vulnerable to erosion by the sea once uncovered

the coast, together with the inaccessibility of many locations in relation to modern infrastructure. Nevertheless, an understanding of submerged sites and landscapes is highly significant for the continent because not only does it provide an important link related to a full understanding of the inhabitation of the ancient landscape, but also it provides vital information relating to the arrival of the first human population. Finds to date place the earliest human activity around 47,000 years ago, at a site named Lake Mungo, at the Willandra Lakes, in New South Wales (Attenbrow 2002; Stern 2014). Most commentators suggest the earlier arrival of groups by a sea crossing during a period of sea-level low stand, perhaps across a distance of some ninety kilometres from the submerged continent of Sundaland around the present-day islands of Indonesia (Nutley 2014; Bird *et al.* 2016).

Research to date has focussed on submerged landscapes rather than sites, and goes back to the 1980s and work by divers to record submerged terrestrial features around the Cootamundra Shoals, 200 km northwest of Darwin (Flemming 1986). At this time, no evidence for the human settlement of the landscape was discovered. More recent research has taken place among the island groups off the coasts of northwest Australia, where desktop surveys of archaeology, zoology, geology, geomorphology and past sea-level history have been combined to produce information relating to the submerged landscape and its potential for human settlement (Ward *et al.* 2014; Ward and Veth 2017). Other, more targeted, survey work relating to the submerged landscape has been undertaken in the south of Australia, in the waters of Port Phillip Bay, Victoria (Pl. 31). Using a combination of existing data sets including pollen and seismic research together with climate research and ethnoarchaeological information, it has been possible to reconstruct the palaeoenvironment and link it to known Aboriginal archaeological sites around the bay (Holdgate *et al.* 1981; Steyne 2009). One of the main outputs of this research has been an animation including the wider view of the ancient landscape (Steyne 2016), which is obviously good for both academic and more popular dissemination. Interestingly, this work incorporated a considerable ethnoarchaeological element, making use of Dreamtime stories, from communities with an ancestral link to the bay, which indicate that the floor of the bay was once part of a terrestrial territory.

Investigation to identify actual sites, meanwhile, has been minimal in Australia. Despite the positive results from work on inundated Aboriginal sites in freshwater lakes as at Lake Jasper and Lake Victoria (Dortch 1997; Hudson and Bowler 1997), there has been little fieldwork in marine waters though the potential of submerged rockshelter sites is recognised, as evidenced by diver survey in Port Hacking, New South Wales (Nutley *et al.* 2016). This project seeks to identify submerged rockshelters with the right conditions for the survival of cultural material, place those shelters into a pre-submergence landscape context, and conduct trials of techniques for more detailed examination (Pl. 32). Work to date has identified twelve potential rockshelter sites.

A more general approach has been taken by Nutley in his study of the Australian continent as a whole, which resulted in a predictive model combining archaeological factors related to the positioning of sites with environmental factors related to site survival. Through this work he was able to identify the types of location where sites might be preserved and the biases affecting the submerged archaeological record (Nutley 2006). While research around Australia may not yet be well developed, studies like this are an important way forward that allow resources to be maximised and research effort to be carefully targeted.

Sundaland

As with the other main landscapes discussed in this book, Sundaland comprises the once-exposed lands of an area of continental shelf, the Sunda Shelf, which stretches from Indonesia north to Thailand, Cambodia, and Vietnam (Fig. 9.4). It comprises the largest area of coastal shelf in the world, and includes the waters of the South China Sea, the Gulf of Thailand and the Java Sea. The waters of Sundaland are relatively shallow, and to the east it is bounded by an area of deeper sea that gives on to the Sahul shelf which surrounds Australia and New Guinea. These waters remained as open seas even during the lowest sea-level stands and they played a crucial role in the story of the peopling of Australia because they mean that the early settlers must have used water transport when they arrived. The inundation of Sundaland was already well underway during the Last Glacial Maximum around 17,000 years ago, by which

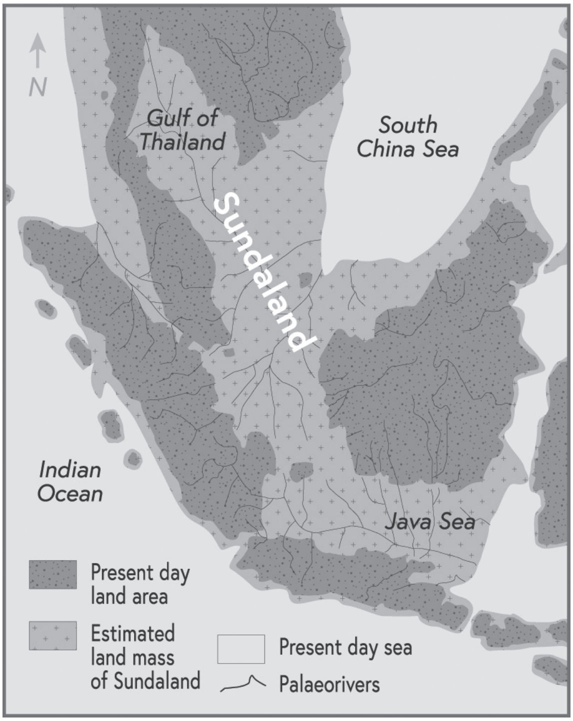

N
Gulf of Thailand
South China Sea
Sundaland
Indian Ocean
Java Sea
Present day land area
Estimated land mass of Sundaland
Present day sea
Palaeorivers

Fig. 9.4 The landmass of Sundaland. Image: Rhona Jenkins

time much of the continental landmass had disappeared, this inundation continued into the Early Holocene.

Sundaland is a significant landmass for several reasons, not least its role as the springboard for the movement of communities into Australia. In addition, perhaps not surprisingly, given its size, it incorporated considerable biodiversity including tropical rainforests, mangrove swamps along the coasts, and several large rivers. Research on the submerged landscapes of Sundaland is still in its infancy. Existing bathymetric data has been used to model likely shorelines and river systems at various time slices (identified using general models of relative sea-level change in the area) with interesting results that highlight the great potential of the area (Voris 2000). Nevertheless, despite this potential, research has focussed on the bigger picture, providing overviews of human settlement, derived from excavations on land, that demonstrate the existence of hunter-gatherer communities here from around 50,000 years ago.

Sundaland underwent less dramatic environmental change than the submerged lands of the north. Nevertheless, the interplay between the slowly rising seas, temperature and precipitation had a profound effect on the changing palaeoenvironment and conditions for the human populations here. As relative sea-levels rose, around 15,000 years ago, there was a rise in temperature due partly to widespread global warming, partly to the increase in warmer, shallow waters and partly to a decrease in the intensity of the monsoon (Pelejero *et al.* 1999). Perhaps for this reason, perhaps for others, existing research suggests that there was little change in material culture and lifestyle with the gradual incorporation of agricultural practices into hunter-gatherer life in the period between 6000 and 2000 years ago (and perhaps earlier, depending on your definition of agriculture). This incorporation has been described as an 'entanglement' (Barker and Janowski 2011b). Interestingly, the narrative relating to the early population of Sundaland depends on a mixture of archaeological, linguistic, and DNA evidence and the interpretations do not always agree (Barker and Janowski 2011b; Oppenheimer 1999; Soares *et al.* 2008), but this keeps the discourse flowing.

The initiation in 2015 of underwater training with the aim of building an underwater archaeology department at the Institute of Archaeology in Hanoi, Vietnam, is an exciting development for research into the submerged landscapes of northern Sundaland (Borghuis and Manders 2015).

Japan

The study of submerged landscapes in Japan is complicated by the active tectonic history of the region, but, in general, relative sea-level around Japan has been considerably lower than today for much of prehistory, revealing a submerged landscape that stretched, at times, towards Korea. In addition to marine locations, underwater archaeology in Japan has examined sites and landscapes in inland freshwater lakes, and there has also been an emphasis on site formation and preservation processes as well as survey work (Hayashida *et al.* 2014). Over 200 sites have been recorded, dating from the Palaeolithic onwards and incorporating a range of features from different types of shell middens to artefact clusters and timber remains (Hayashida *et al.* 2014). Though the underwater cultural resource is clearly taken very seriously in Japan, not least for its contribution to the overall understanding of prehistory, few sites have been excavated, or examined in detail. At Takashima, in Nagasaki Prefecture, excavation below a historic battle site has revealed a Jomon site with various remains including pottery and other artefacts, all likely to date before 8500 years ago when the area flooded (Takashima-cho board of Education 1993). In Okinawa Prefecture, a number of disturbed shell mounds have been recorded from the mouth of the River Urauti (Fig. 9.5) (Hayashida *et al.* 2014). Work in Japan includes much public education, as well as technical investigation (Katagiri *et al.* 2014).

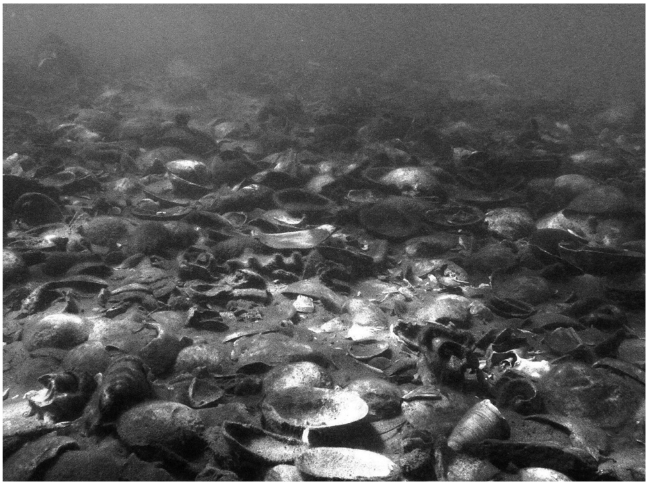


Fig. 9.5 The shell midden deposits at Katsuura shell midden, River Urauti Japan. Image: Jun Kimura

India

The submerged landscapes of the Indian continental shelf have considerable archaeological significance both for their potential location along the southern extensions of the global 'Out of Africa' migration routes and for their contribution to understanding of the archaeology of India (Flemming 2004a). Sea-level research indicates that there have been periodic fluctuations above and below present relative sea-level throughout the Holocene around the coasts of India (Sundaresh *et al.* 2004; Rajani and Kasturirangan 2013), a situation further complicated by local topography and sea conditions. Several universities have created underwater archaeology centres and, in addition, the Underwater Archaeology Wing of the Archaeological Survey of India has been conducting research into the submerged landscapes of the continental shelf around the country (http://asi.nic.in/underwater-archaeology-wing/). Research has comprised mainly survey work, but some excavation has also been undertaken. In some places, local conditions have resulted in the flooding of relatively recent remains, so that there is a historic element to the cultural landscape here that is not always apparent elsewhere. This adds to the studies of submerged archaeology, though it can make both excavation and management more expensive. Not surprisingly, the potential of submerged remains such as these can also be expressed in local tradition, though in most places considerable work is necessary to verify sites and elucidate precise dates of occupation and the mechanisms of submergence (Rajani and Kasturirangan 2013).

The coastal city of Dwarka in Gujarat, figures as a significant location in tradition relating to Krishna, one of the main protagonists in the *Mahabharat*, an ancient epic.

The story tells of the grandeur of the ancient city and of its loss below the waves. The strength of the legends is such that Dwarka has been regarded as of archaeological interest since the beginning of the twentieth century and was one of the first places where underwater archaeology was practised in India. Ongoing work comprises mainly diver survey and remote sensing (Pl. 33), but with some excavation, and has recorded plentiful evidence for a flourishing fishing port in operation from the 8th century AD until it was destroyed by coastal erosion, possibly as recently as the 15th century AD (Gaur *et al.* 2004; 2005).

The loss of ports to a combination of coastal erosion and relative sea-level rise has taken place around India and is often referred to in oral history. In many cases, archaeological investigations have taken place to explore the veracity of these traditions and, if possible, provide quantitative detail. Sundaresh and Gaur (2011) summarise work, including intertidal as well as sub-sea surveys, at sites like Poompuhar and Tranquebar. Another important port in this area of Tamil Nadu is Mahabalipuram, renowned in ancient texts for its religious significance, and temples, as much as for its position as an important trading centre. Underwater research here has included geophysical survey and diving and revealed the remains of both secular and religious structures going back to the 8th century AD (Rajani and Kasturirangan 2013). At Saluvankuppam, a little over a kilometre to the north of Mahabalipuram, earlier structures, dating back to the 4th century AD have been found. Coastal erosion seems to have played a significant role in the destruction of these sites, too (Sundaresh and Gaur 2011).

The significance of the submerged cultural history of India is clearly recognised and subject to an active programme of research. Nevertheless, as many authors point out, precise confirmation of the detail presented by oral history in the underwater remains is difficult (Sundaresh *et al.* 2004). So far, work in India has focussed on historic sites rather than early landscapes, though the potential for the survival of earlier archaeology is recognised (Flemming 2004a; Tripati *et al.* 2004).

The Arabian Gulf and the Red Sea

The area of the Arabian Gulf and the Red Sea is of particular interest for the study of submerged landscapes because it covers one of the favoured locations through which early modern human populations may have crossed out of Africa to begin their migration and population around the globe. For many years, traditional research focussed on a land route out of Africa, across the Sinai Peninsula, towards the Levant, but new investigations examine the possibility of short sea crossings made available during periods of sea-level low-stand at various times in the Pleistocene (Harff *et al.* 2016). Bailey points out that the language used to describe this movement of peoples is misleading, suggesting as it does targeted migration. Rather, a process of gradual expansion and 'accidental' colonisation by small, possibly family, groups is more likely (Bailey 2015).

Research into the archaeological potential of the southern Red Sea integrates terrestrial and underwater investigation and incorporates interdisciplinary studies including palaeoenvironmental work, undersea work and more conventional terrestrial archaeology. A recent focus on the region has been facilitated by Bailey and colleagues through the DISPERSE Project (Bailey *et al.* 2015). Essentially, this research argues that, at periods during the past, the arid conditions of desert regions such as the Arabian Peninsula were replaced by a wetter, less extreme environment and that, at times, in combination with sea-level low-stands, this would have facilitated the dispersal of early modern human groups out of Africa. Attention has focussed on a broad period between 200,000 years ago and 50,000 years ago, and depends on the theory that these early human groups were able to exploit coastal resources and undertake short sea crossings (as attested by the dispersal of groups into Australia, Bailey *et al.* 2015).

With regard to the expansion of early modern human groups out of Africa, research into palaeogenetics places this movement around 60,000 years ago (Mellars *et al.* 2013). Mellars and his colleagues link it to the productivity of coastal waters (and related productivity on land) and Bailey (2015) has linked it to bathymetric and sea-level modelling (taking into account relevant factors such as volcanic activity, salt doming, and sedimentation) which suggest that the crossing out of Africa may have involved navigation of a narrow channel, no more than four kilometres wide, making use of a chain of islands (Lambeck *et al.* 2011b). Bailey goes on to consider the palaeoenvironmental evidence which has identified periods of improved climate that would have facilitated movement through areas now considered to be desert. He notes the extended coastal terrain available on both sides of the Red Sea when relative sea-levels were lower; terrain which, while the archaeology on land suggests that it may well have been settled in early prehistory, is now only available as a resource for studies of submerged landscapes and sites because of the rise in relative sea-levels since the period (Bailey 2015).

Absolute archaeological evidence that the submerged landscapes of the southern Red Sea were used by early modern populations as they expanded out of Africa has yet to be found, but in its absence, the contribution of related studies suggesting that this was, indeed, the scenario, is compelling. Ongoing work by Bailey and his colleagues is now investigating the archaeological potential of the submerged landscape around the Farasan Islands (Pl. 34) with the use of sidescan survey, seismic profiling, diver survey, remotely operated vehicles, and sediment cores (Bailey 2015; Bailey *et al.* 2017c).

Although absolute data relating to the date of the most recent marine transgression in the Arabian Gulf and Red Sea is lacking, research suggests that a substantial submerged landscape existed across much of the area up to 8000 years ago. Construction work on a bridge between Qatar and Bahrain has been used as an opportunity to conduct both geophysical and diver surveys with the aim of investigating the potential of the area for submerged archaeology (Al-Naimi *et al.* 2012). Remote sensing using sidescan sonar revealed a number of anomalies, as well as providing characterisation of the underwater landscape. A variety of anomalies were then surveyed visually by divers, and, while most were modern in origin, and some were natural, there were others which would merit further investigation. Further work in the region is planned.

Africa

The history of change in relative sea-level around the continent of Africa is dependent on local conditions just as it is in other places around the globe. Research and understanding into the submerged landscapes of the African continental shelf varies greatly from country to country, and has yet to take off in many places, but one country with a burgeoning history of investigation is Tanzania, where recent underwater remains mix with potentially older material. Another nation where the boundary of archaeology does not stop at the shore is South Africa where the contribution of the extended landscape to understanding of the earliest populations is becoming increasingly apparent (Werz *et al.* 2014).

Tanzania

The coast of Tanzania runs for over 1400 km, and borders the Indian Ocean, it includes various islands and archipelagos. Seafaring and coastal activities have played an important role in shaping the cultures of the country from earliest times, and research inland confirms the long-standing significance of aquatic resources for those communities living on freshwater lakes and rivers as well (Ichumbaki 2015). Relative sea-level change along this coastline has been driven by the interplay of world-wide changes in sea-levels together with local tectonic movements. As a result, inundation, erosion, exposure and sedimentation have all to be taken into account (Pollard 2009). From at least the 1st century AD, coastal activities have looked outward, to include trade and cultural exchange as well as facilitating local developments. In some places, the underwater cultural heritage of Tanzania comprises material that relates to historic times, such as at the island of Kilwa Kisiwani, where the ruins of an ancient trading centre include submerged remains (Fig. 9.6).

Kilwa Kisiwani, was a significant maritime trading centre (now recognised as a World Heritage Site), located on an island off the southern coast of Tanzania, and making use of sheltered inlets while maintaining access to the Indian Ocean. At the end of the 1st millennium AD, falling relative sea-levels allowed expansion of the settlement on to

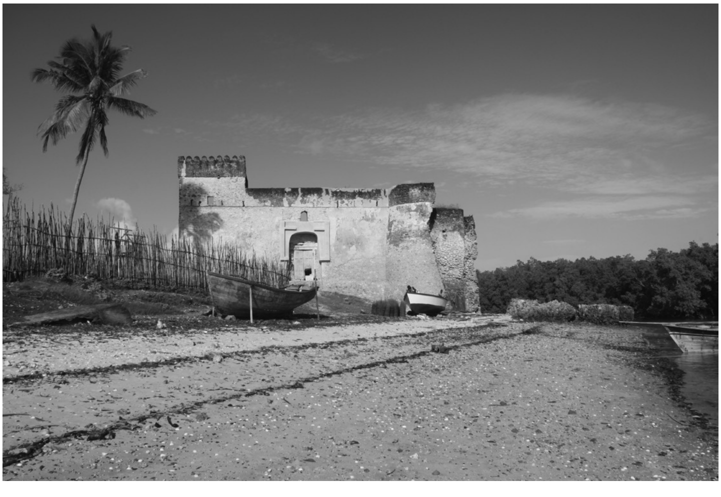


Fig. 9.6 The Portuguese fort at Kilwa Kisiwani illustrates the fragile nature of many of the sites here, at the edge of the intertidal zone. Image: Edward Pollard

low lying sand terraces which were subsequently eroded and inundated when sea-levels started to rise in the late 14th century (Pollard 2009). Work by Pollard and others to combine the results of survey in the intertidal zone with an understanding of the mechanics of relative sea-level change here has helped to elucidate the history of the town and of the way in which its inhabitants adapted their structures to the changing local geography (Fig. 9.7) (Pollard 2008). As a result of the rising relative sea-levels in the latter years of the site, a sea wall and various outworks were constructed to protect the harbour, though these were not subsequently maintained once the port diminished in importance (Pollard 2009). Research at Kilwa has included marine archaeological survey, involving both remote sensing and divers, in the immediate offshore zone (Bates and Pollard pers. comm. March 2018). In addition to various anomalies with high potential as cultural heritage, it was possible to characterise features in the submerged landscape such as channels and coral shelves. Interestingly, the work at Kilwa Kisiwani has included work with the local community and the collection of local oral histories relating to the history of the site and the activities undertaken there (Jeffery and Parthesius 2013).

Submerged coastal remains such as these, and others relating to both large centres and humbler sites, have been recorded in many locations in Tanzania, such as in the Mafia islands at Kisimani Mafia (Jeffery and Parthesius 2013); and at Kaole to the north of Dar es Salaam (Pollard 2009). In general, study of the underwater landscape here has focussed on these sites, rather than on the broader submerged landscapes that are sometimes of interest in relation to earlier prehistory elsewhere. This is not to diminish the significance of this work, it is an important aspect of the investigation and management of underwater cultural heritage and reflects both the great variety of potential remains with which cultural managers have to be concerned and the problems of investigation and management in a world of limited resources.

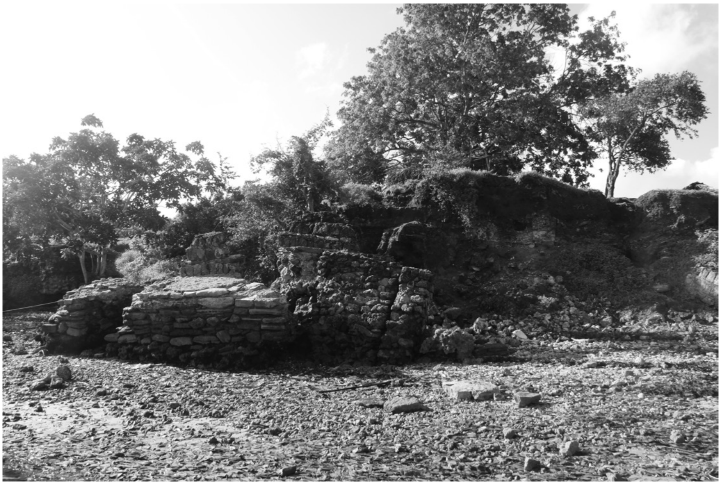


Fig. 9.7 The remains of the Omani Quay at Kilwa Kisiwani in a vulnerable position on the shore. Image: Edward Pollard

South Africa

The continental shelf of South Africa varies in width but extends to over 200 km around the southern coasts. At various times in the Pleistocene it has emerged as a landscape, though the precise history of emergence and subsequent rates of submergence is still being investigated. Along the southern coastal plain of South Africa the emerged landscape offered an extensive habitat favourable to early human populations from early on, but fluctuations in relative sea-levels have impacted greatly on the extent of land available, connections to the rest of the African continent, and the type of resources available over time. A combination of aDNA evidence, resource analysis, and sea-level history have led some to argue that areas such as this may have played a key role in encouraging early hominin populations to adapt to use marine resources in order to supplement their emerging hunting skills (Compton 2011). For this reason, investigation of the submerged landscape of South Africa includes detailed work on the palaeoenvironment(s) and resources, as much as it includes research on potential archaeological sites.

Cawthra and colleagues used remote sensing including both multibeam bathymetry and sidescan sonar together with sediment and rock sampling and diver survey in order to observe and analyse the submerged landscape to a depth of 55 m in an area roughly 40 × 10 km off Mossel Bay in Western Cape (Pl. 35) (Cawthra *et al.* 2011). They selected the area because of known archaeological sites (from *c.* 160,000 years ago to recent times) (Marean 2010) on land around Pinnacle Point in the western half of the study area. Their work has resulted in a detailed reconstruction of the changing topography here as relative sea-level fluctuated through the Pleistocene, together with the identification of possible locations for archaeology underwater that mimic those on shore.

Given the postulated roles of coasts and the resources of the sea in facilitating the dispersal of modern humans around the globe, the possible development of marine exploitation on and around the submerged coastal plains of South Africa would have been a significant step for modern humans. The use of marine resources in this region is documented in sites like Blombos Cave, dating back *c.* 100,000 years, where changes in the species collected have been linked to the differing distance of the site from the shore as relative sea-level fluctuated throughout the Pleistocene (Langejans *et al.* 2012). Work at Pinnacle Point indicates that activity here goes back at least 160,000 years (Marean *et al.* 2007) when relative sea-level was lower and the site lay much farther from the shore. Nevertheless, Bailey and Flemming have pointed out the difficulties in interpreting the significance of this evidence without information from, as yet undiscovered, similar sites in the submerged landscape (2008).

Despite the identification of landforms suitable for human settlement on the submerged landsurface of South Africa (e.g. Cawthra *et al.* 2011), detailed analysis of the human settlement of the southern coastal plain during sea-level lowstands has not been undertaken. The submerged find of two Acheulean handaxes and a bifacial artefact, all of local quartzite, in what is considered to be a roughly original location, at a depth of about 8 m, in Table Bay, Cape Town indicates that humans were present at least 300,000 years ago and perhaps as much as 1.4 million years ago (Werz and Flemming 2001). These finds were, however, made accidentally during excavation of historic wreck sites; around the globe the identification of prehistoric artefacts underwater often still occurs by chance.

The submerged marine landscapes of South Africa hold considerable potential to provide globally significant information relating to early human adaptions and settlement, but there is much work to be done. While investigation of the ancient landscape has provided some detailed information relating to topography and resources, the vagaries of topographical and chronological change mean that there are still large areas of the ancient coastal plain that require investigation. Archaeologically, given the biases inherent in any study that only considers existing terrestrial sites, research to identify and investigate underwater remains should now be a priority. Two potential avenues for prospection comprise the investigation of submerged cave and rockshelter sites, and the development of techniques to locate artefacts such as handaxes underwater. While the latter is not going to be easy, work elsewhere has started to explore the possibilities (Hermand *et al.* 2011).

10. Submerged landscapes around the world: The Mediterranean and the Black Sea

In addition to the interplay of glacial and post-glacial isostatic and eustatic change, the submerged landscapes of the Mediterranean have been subject to the impact of ongoing tectonic activity, in particular (but not solely) earthquakes, because of the junction of tectonic plates here. This adds complexity to the study of submerged archaeology in the Mediterranean, but it has also led to some remarkable preservation due, among other things, to the rapidity of inundation. Like other examples around the world, the submerged landscapes of the Mediterranean are important both for the potential role of coastal areas in facilitating the dispersal of early humans into wider geographical areas and for the occurrence of archaeology relating to activities such as settlement and trade.

North Africa and the southern islands: A submerged landscape?

The possibility of a land and sea crossing extending northwards from the North African coast towards the island of Sicily has served to focus research attention in this area, known as the Sicily Channel, for a while. At present the archaeological evidence suggests that human colonisation, when it took place, came down from the north, but that has not prevented research work from keeping an eye out for possible indications of migration from the south.

Roughly halfway between North Africa and Sicily lies the volcanic island of Pantelleria. Though no clear archaeological evidence for the occupation of Pantelleria prior to the Chalcolithic period (late 6th millennium BP), has been found, obsidian from Pantelleria does occur on Neolithic sites around the central and western Mediterranean, suggesting that people had reached the island prior to this period (Abelli *et al.* 2016). The influence of past relative sea-level rise on the visibility (and thus understanding) of archaeological material in Pantelleria has been taken into account by some who consider it a factor relating to the difficulties of identifying earlier, potentially submerged, evidence. Thus, Rapisarda (2007), has postulated the early use of now submerged obsidian sources.

A recent project by Abelli and colleagues has been putting together information relating to the submerged landscape around Pantelleria, likely sea conditions in earlier times, with information relating to the finds of prehistoric material at a depth of 18–21 m in the bay of Cala Tramontana on the east coast of the island. In the bay itself, detailed remote sensing work, supplemented by diver survey has been used to investigate the submerged topography. Underwater work then proceeded to include the recovery of over 700 stone flakes, cores and tools, by means of a suction pump employed across a horizontal survey grid that could be subdivided down to one square metre. Use of the pump could also be controlled in order to provide horizontal stratigraphy in half metre spits (Abelli *et al.* 2016). Most of the artefacts recovered are of flint, four are of obsidian.

The significance of the finds from Cala Tramontana relates to the topography of the submerged landscape in this area. While the landscape of today is comparatively difficult to access, lower relative sea-levels in the past (estimated to be some 15 m lower than today around 7700 cal BP) suggest that accessible landing places may have coincided with obsidian sources in this part of the island. The finds all lie in reworked seabed sediments, and the researchers suggest that they derive from an original site slightly nearer in to the present coast, and perhaps in slightly shallower waters. This means that accurate dating has not been possible, but dating of the adjacent lava units has been suggested to the mid-9th millennium BP (Abelli *et al.* 2016). These dates support earlier research (Rapisarda 2007), suggesting that the exploitation of local obsidian may go back at least to the 9th millennium BP and made use of currently submerged sources. Although Abelli and colleagues consider that it likely relates to episodic visits to the island rather than permanent human occupation, it is clear that information derived from land-based archaeology does not provide the whole picture of Pantelleria's early settlement.

The Maltese archipelago, to the southeast of Pantelleria and also in the Sicily Channel, forms another important component of any hypothetical early route for human dispersal northwards out of Africa. Research here has focussed on the reconstruction of the submerged landscape at key points in time (Foglini *et al.* 2016). It considers deeper waters than many other studies and thus aims to shed light on local conditions extending back as far as 20,000 years. Work by Lambeck and others indicates that relative sea-level in this area at the Last Glacial Maximum (*c.* 20,000 years ago) was around 130 m lower than today (Lambeck *et al.* 2011). Research on the submerged landscape here integrates high resolution multibeam bathymetry, sediment analysis and LiDAR data to produce a detailed model of the continental shelf down to 130 m below present sea-level around the islands (Foglini *et al.* 2016). It has been possible to identify various landscape features, sometimes relating to known landscapes of the islands today such as limestone sinkholes and pavements, together with more general features such as river channels.

This research suggests that Malta was connected to Sicily by a land bridge from around 20,000 years ago until around 13,000 years ago, and that a substantial landscape around the archipelago remained exposed until some 10,000 years ago. It also indicates that much of this submerged landscape is covered today by more recent sediments, but that areas of potential preservation do occur and may be suitable for the preservation, and recovery, of archaeological deposits. It does, however, note the lack of archaeological material recovered from the area to date, meaning that, in the absence of further, targeted, work, the possibility of early human activity here remains hypothetical (Foglini *et al.* 2016).

With regard to the movement of peoples into southern Europe, Sicily occupies a key location, of interest for the possibilities of links to the north through the Straits of Messina as well as to the south across the Sicilian Channel. Despite evidence which suggests the possibility of the existence of early human communities in Italy by 45,000 years ago (Benazzi *et al.* 2011), details of the earliest occupation in Sicily remain obscure. Settlement prior to the emergence of a northern land bridge would have required the use of watercraft across potentially difficult waters and, at present, the suggestion that Neanderthal groups were seafarers (Ferentinos *et al.* 2012) is still controversial. To date, the earliest dated archaeological material in Sicily relates to the cave sites of Addaura and San Teodoro where there are human remains dated to around 16,000 years ago (Mannino *et al.* 2011). Today the crossing from Sicily to Italy is known for its strong currents; currents which inspired classical myths of formidable and aggressive sea deities. Recent research has aimed to investigate the past history of this crossing, in particular the existence of a land bridge here, the dates of its emergence and later inundation and the sea conditions as relative sea-levels rose (Antonioli *et al.* 2016). In order to achieve this, a combination of remote sensing, sediment analysis, diver survey, oceanography, geomorphology, tectonics and geography has been employed. In addition, information related to the spread of mammalian fauna to Sicily has been included. The results suggest that a land bridge emerged around 25,000 years ago and may have lasted until around 17,000 years ago when it was submerged (Antonioli *et al.* 2016). Prior to this, the research suggests that the Straits of Messina were subject to currents and tides strong enough to preclude early navigation. It is thus assumed that the first human settlement in Sicily made use of the land bridge from the north.

Further south in Sicily, on the eastern coast to the north of Syracuse, research has sought to tie submerged archaeological sites from the Bronze Age (3800–3200 BP) and Greek Archaic period (2700–2500 BP) in to information related to the palaeogeographical development of the coast (Scicchitano *et al.* 2008). Change in relative sea-level here is due to a mix of eustatic and glacio-hydro-isostatic change together with tectonic instability. Four archaeological sites were selected for investigation, including the Bronze Age sites of Ognina and Thapsos, the Greek settlement of Megara Hyblaea, and a quarry, also of Greek date, at Punta della Mola. All of these sites hold land-based material as well as submerged remains just offshore suggesting that for part of the period during which each was active, at least, relative sea-levels were lower. No new archaeological survey was undertaken for this work, but existing remains were visited and observed by divers. The research then combined archaeological interpretation (assuming that a functioning site sat at least above the reach of the highest tides) together with palaeogeographical understanding in order to calculate possible uplift rates and well as rates of change in relative sea-level. Precise measurements from sea-level indicator points are still lacking here, but the research does provide an important step forward towards understanding landscape change in the area.

The eastern Mediterranean: Landscapes

In addition to modelling the submerged landscapes and investigating the traces of prehistoric settlement, research in the eastern Mediterranean also focusses on the substantial remains of inundated towns and cities, a result of tectonic instability.

The northeast Mediterranean is of especial interest for studies of the movement of early humans into Europe, offering as it does both a coastal route into the region from Africa and Asia, and the resources for longer term settlement (Galanidou 2014). During the Pleistocene, the evidence suggests that lower relative sea-levels resulted in a greater landmass here. In a useful overview of existing evidence in the Aegean, Sakellariou and Galanidou (2016), note that Palaeolithic finds, comprising both artefacts and human skeletal fragments, from the region go back to the Lower Palaeolithic and relate to both mainland and island sites. Finds in Crete suggest that anatomically modern hominins may appear in the south of the area as much as 200,000 years ago (Strasser *et al.* 2010), and some interpret this evidence as an indication that anatomically modern hominins were able to make sea crossings from an early date as well as travel by land (Sakellariou and Galanidou 2016). Elsewhere in the Aegean, the archaeological material from the islands suggests that other hominin groups, including Neanderthal communities, were also making sea crossings (Ferentinos *et al.* 2012). These were, it seems, busy waters that offered the ideal conditions to nurture the skills of those who wished to expand their horizons.

Detailed understanding of the changing geography across the eastern Mediterranean is thus a vital component of research into many aspects of early human activity here, not just the broader patterning of early settlement. The occurrence of Palaeolithic sites on islands indicates the ability of the hominin population as seafarers, though precise information related to relative sea-levels, local shorelines, and palaeo-tides and currents, is necessary in order to assess the levels of skill and knowledge required. Ferentinos and colleagues discuss the ways in which local conditions changed constantly between the Ionian islands and the Greek mainland in the period between 100,000 years ago and 8000 years ago so that the stretch of water separating islands from mainland varied between 5 km and 12 km (2012). They suggest that sea crossings of up to 12 km may have been made here by Neanderthal groups from as much as 60,000 years ago. Wider and more challenging crossings are proposed as early as 130,000 years ago by Strasser and colleagues on the basis of finds in Crete (Strasser *et al.* 2010; 2011). Elements such as this are a vital part of our understanding of the emergence of skills in early populations, including both Neanderthals and anatomically modern humans. Given the rapid expansion of seafaring and coastal specialisation in early post-glacial populations around the world (Wickham-Jones 2014), research into the earlier development of seafaring abilities and the exploitation of coastal resources is important.

Although understanding of the submerged landscapes of the Aegean is undoubtedly important for research into the early archaeology of the region, it is affected by the tectonic history of the area (Sakellariou *et al.* 2017). Many active faultlines occur here and earthquakes, volcanic activity, and undersea landslips are all common, in addition to the same type of changes in relative sea-level recorded elsewhere. Research has tended to be broadscale and rely heavily on modelling, though Sakellariou and Galanidou highlight the importance of an understanding of the submerged landscapes and likely resources, both flora and fauna, in order to interpret the archaeology (2016). Their work provides a useful summary of existing research in the area, identified landscape features, possible resources, and likely pockets of preservation for both landscape and archaeological research. In addition, work in the Ionian Sea has incorporated marine geophysical survey and diver observation and sampling with the aim of providing more precise detail for palaeogeographic reconstruction (Zavitsanou *et al.* 2015; Zavitsanou 2016). The broad span of submerged archaeology across the Aegean is demonstrated by occurrences of submerged Classical and Hellenistic material such as the harbour works examined offshore of Lesbos (Williams 2007; Theodoulou 2008).

Elsewhere in the eastern Mediterranean, awareness of the existence of a submerged landscape has prompted fieldwork to investigate the possibilities of recovering archaeological finds, though all too often understanding of the topographical history of an area is provided from generalised modelling rather than site specific analysis (Galili *et al.* 2017). As seen from research elsewhere (Bates *et al.* 2013a; 2016) this can lead to highly misleading interpretations of the precise timing and rates of inundation at specific sites, thus biasing understanding of the results. Nevertheless, this initial work is an important step in highlighting the potential of more detailed, comprehensive projects. In Cyprus, investigative diver surveys at several sites have led to the identification and recovery of stone tools at a depth of 9–12 m from one site, Dive Site C at Akamas (Pl. 36), Aspros on the western coast of the island (Ammerman *et al.* 2011). Excitingly, analysis of the material leads to the conclusion that the site dates to the Late Palaeolithic (Kacanowska and Kozlowski 2014), adding to the emerging picture of navigation from an early period (Ammerman 2014). The shoreline here, some 12,000 years ago would have been about 70 m lower than today. Elsewhere in Cyprus, palaeogeographical work has taken place with the aim of reconstructing ancient coastlines and coastal processes related to the late Quaternary and Early Holocene with the aim of tying this in to understanding of the submerged landscape and possible inundated prehistory (Galili *et al.* 2016; 2017).

The coasts of Anatolia border on the Aegean, the Mediterranean, the Black Sea and the Sea of Marmara, and the history of submergence here includes eustatic and isostatic changes as well as tectonic change, resulting in the potential for prehistoric remains as well as more recent sites (Özdoğan 2011). Research along the Turkish coasts includes the recording of sites dating to the both the Bronze Age and Classical periods (Pl. 37) as well as some palaeogeographic work, especially that related to the formation of the Bosphorous. Unusually, the submerged archaeology includes the remains of several prehistoric shipwrecks which, though not strictly a part of the submerged landscape, do help to shed light on both the human lives and wider palaeogeographies of the area (Özdoğan 2011).

The eastern Mediterranean: Villages and towns

In Israel, research has focussed along the Mount Carmel coast where the remains of several submerged sites have been recorded, mainly in shallow waters close to the coast. At the Neolithic site of Atlit-Yam, dated to around 8000 years ago, the remains of a variety of stone-built structures survive on the seabed at a depth of 8–12 m. Work here has incorporated survey and excavation with remarkable results (Galili and Rosen 2011). The remains include dwellings, as well as megalithic settings (Pl. 38), lengths of walling, and several wells, two of which have been excavated (Pl. 39). Organic materials are well preserved and include finds that rarely occur on land such as wooden vessels and reed mats. The community were established farmers with both crops and animals, though they also harvested local wild resources from both land and sea. By the 6th millennium BP there is evidence for the extraction of olive oil on site. To the east of the settlement lay a substantial cemetery of stone-built graves (Pl. 40) with evidence of ceremonial activities in the form of deposits of charred seeds.

The excavation of Atlit Yam is a clear indicator of the high potential of submerged sites here, and other submerged village sites have been recorded along this stretch of coast, but there is, as yet, little work to reconstruct precise heights and rates of past relative sea-level change in the region. Existing work has tended to use inferred data from archaeological and sedimentological proxies rather than the precise dating of accurate markers, though it has been tied in to general bathymetrical information and this does go some way towards providing a palaeogeographical reconstruction of the offshore zone at different time slices (Galili *et al.* 2017; 2005). The generalised model for past relative sea-level change here suggests considerable change further back in time, opening the (as yet unexplored), possibility of earlier sites in deeper waters further offshore (Galili and Rosen 2011).

To the west lie the extensive remains of the submerged town of Pavlopetri in southern Greece, which are well known and provide a nice foil to the elusive archaeology of earlier periods. The site extends across at least 40,000 m^2 in shallow water, up to 4 m deep, and investigation has included both survey and excavation (Henderson *et al.* 2011). The earliest activity here has been dated to around 5500 years ago, and the most recent material includes pottery sherds from the 7th century AD. This work illustrates the value of detailed survey: overall plans provide a clear view of the town, including dwellings, roads and other buildings; while more detailed plans have been combined with digital scanning in order to build an intimate view of individual structures. The submergence of Pavlopetri has been ascribed mainly to tectonic disturbance and this led to the complete abandonment of the town by the later Roman period.

The eastern Mediterranean: Classical port cities

The classical underwater sites of the eastern Mediterranean are best represented by the submerged archaeology of Alexandria and related sites in Egypt. Alexandria was a flourishing maritime city, founded by Alexander the Great in 331 BC, and with widespread trading connections. The location chosen by Alexander was already a prosperous port and the submerged remains of the city incorporate material with some chronological depth, including well-preserved stone buildings as well as all the ephemera of a classic ruin: columns; statues; temples and so on (Pl. 41). Perhaps most important are the remains of the great lighthouse, the Pharos, which comprised one of the wonders of the ancient world. At its height, Alexandria is reported to have had a population of over a million inhabitants (Tzalas 2000). Alexandria was only one of several ports that flourished along that stretch of coast. The modern town of Abu Qir, some 22 km to the northeast, is known to occupy an area once served by three ports: Canopus, Thonis-Heracleion, and Menouthis, all of which stood on ancient distributaries where the Nile flowed into the Mediterranean. The loss of the settlements along this coast was in part due to gradual silting at the mouth of the Nile delta, but also exacerbated by earthquake activity, in particular, a devastating earthquake, and possibly a tsunami, in the mid-8th century AD.

Systematic examination of the submerged remains of Alexandria started in the 1990s, though observations of material below the waters of the port had been made from as early as 1930 and there were occasional examples of the recovery of finds such as the raising of a statue together with other antiquities by a group of navy divers in 1962 (Morcos 2000). The results include information relating to the construction of harbour works, religious and commercial structures, as well as domestic dwellings, but they have only touched a fragment of the original city. Much of the work has focussed around the area of the Pharos (Empereur 2000) and it includes diver observation as well as remote sensing (combining techniques such as sidescan sonar and seismic profiling) with the aim of mapping the various harbours (Goddio 2000; Chalari *et al.* 2009). In all, thousands of research dives have been made and it has been possible to reconstruct the topography of the harbour in some detail and match it to ancient accounts such as that made by Strabo around 30 BC. With regard to future management, research includes investigation of modern conditions such as the modelling of waves, currents and sedimentation (e.g. Aelbrecht *et al.* 2000).

The remains of other classical ports lie around the Mediterranean both underwater and on land, including those at Byblos in Lebanon (Frost 2000), Sabratha and Leptis Magna in Libya (Bonacasa 2000), Thasos in Greece (Simossi 2000), Ostia and Antium in Italy (Felici 2000). These sites were submerged for a number of reasons including silting and tectonic activity, and their study and analysis occupies a midway position between that of the prehistoric submerged landscape and shipwreck archaeology (Marriner and Morhange 2007).

The northern and western shores of the Mediterranean

A lack of detailed investigation of the western half of the Mediterranean precludes division of the information here into landscapes and sites. The potential for submerged archaeology has not been lost on keen researchers, but projects are wider spaced geographically and it is harder to tie them in to one another. The modelling suggests that along the eastern shores of the Adriatic, relative sea-level rose from *c.* –27 m to –13.5 m between 9000 and 7500 BP (Benjamin *et al.* 2011b). A number of tantalising find spots have been recorded by Benjamin and his colleagues, including isolated finds of prehistoric stone tools at a depth of 1.5–2.5 m in Veštar Bay in Croatia and, in waters 26 m deep, at Punta Piran in Slovenia, though the latter is unlikely to be *in situ*. A larger stone artefact assemblage was recovered from shallow water at Cape Gale, and the examination of redeposited material from dredging at a depth of 2 m in Veruda Bay yielded considerable amounts of mixed archaeological material including two polished stone axes and other stone artefacts as well as animal bones and later pottery. In 1977, a lithic assemblage of possible (but unconfirmed) Palaeolithic affinity was recorded by Brusić from the sheltered waters off Stripanac Island in Croatia and further lithics

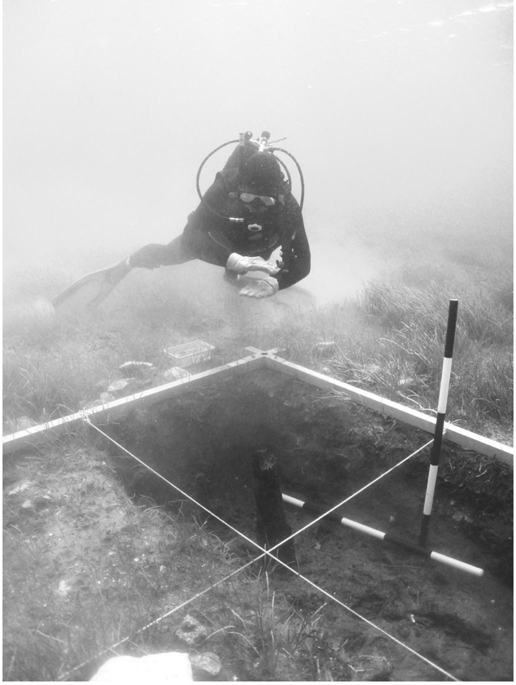


Fig. 10.1 Zambratija Cove, a diver recording the wooden piles. Image: Archaeological Museum of Istria (Croatia)

were recovered at a depth of 5–6 m off the resort town of Baška Voda (Brusić 1977). Detailed examination of these assemblages has yet to be undertaken, and there is little information on context and possible stratigraphy but (with the exception of the Stripanac Island finds) most seem to relate to the Neolithic. The most significant finds relate to work at Zambratija Cove in Croatia, where the examination of more recent material uncovered earlier timber fragments, including oak piles (Fig. 10.1), covering an area of some 30 × 67 m at a depth of between 2.4 m and 3 m (Koncani Uhač 2009; Koncani Uhač and Čuka 2015). The remains are interpreted as the structural elements of a substantial prehistoric settlement and have been dated to around 6000 BP. Wider survey work here has been combined with detailed excavation. The finds from the site include prehistoric pottery, stone tools and environmental material. The broader palaeoenvironmental analysis suggests that the settlement lay in marshland, near to the coast. Sadly, no comparative sites have been recorded from the western, Italian, shores of the Adriatic, but in general, the evidence would suggest that the Adriatic holds considerable potential for the preservation of submerged landscapes and sites and that this is likely to be a crucial element of understanding the landscape history here.

In the south of Italy, the bay of the popular coastal town of Porto Cesareo has been known since the 1960s to hide archaeological remains including Roman and prehistoric material and structures in water that is up to 3.5 m deep. Only in recent years, however, has research been undertaken to place these into a palaeogeographical context that includes information relating to changes in past relative sea-level (Alfonso *et al.* 2012). Fieldwork here focusses mainly on land, but has extended to include the underwater zone. Archaeological finds are tied in to geomorphological understanding through the application of interdisciplinary survey including prospection and sediment sampling. The last 5000 years have been identified as the most significant for change in the coastal landscape, and mean relative sea-level 2000 years ago is estimated to have lain around 1.5 m below present sea-level. The research here has identified a possible tectonic element which may have served to increase the subsidence of the land. This research is crucial to a proper understanding of the development of settlement in this area including information related to the development of fortified settlements in the 4th millennium BP and the seasonal use of coastal resources by small communities in the Roman period.

The western coasts of Italy lack published accounts of research into submerged prehistoric sites, though examples of Roman remains beneath the present waters of the Mediterranean are well known. The Roman resort town of Baiae was a thriving centre from around 200 BC to around AD 500; it lay to the west of Pompei, but is now, almost entirely, submerged under the Bay of Naples. Its remains comprise one of the largest underwater sites in Italy and it has been classified as an underwater archaeological park which may be visited by tourists as well as those wishing to undertake research. The extent of the underwater remains was first discovered from the air in the 1940s, and research continues to shed light on the site. Research has included diver survey and excavation, as well as prospection using various techniques (Paoletti *et al.* 2005). Baiae is located within a very active volcanic area with a history of uplift as well as submergence, movement here is ongoing so that survey to assess the state of the submerged resource over time is vital. Paoletti and colleagues have built on previous work to develop methods, including the use of magnetometry to record magnetic susceptibility and build a model of archaeological features including structural remains such as walls and floors and even some cut features such as pits that can be monitored over time. The work at Baiae provides a good example of how detailed surveys can provide an excellent base data set in order to assess the value of new techniques.

The remains at Baiae include those of fishponds, created by wealthy Romans to provide food. Although there were big, commercial developments, it was also popular for wealthy Romans who lived on the coast to build elaborate personal fishponds, often with viewing platforms and even bespoke dining areas (Higginbotham 1997; Zarattini *et al.* 2010; Kron 2014). In this way, a wide variety of fish were farmed, some from hatcheries and others using wild fry. In coastal areas with submerged Roman remains, fishponds are a relatively frequent find.

Further to the west, there has been little research on possible submerged landscapes of the Mediterranean (but see Canals *et al.* 2017). There has been little investigation of island groups such as the Balearics and no sites have been recorded in Corsica. The potential impact of past relative sea-level change around the island of Sardinia has been considered, but it provides an interesting contrast to submerged archaeological studies elsewhere, because the approach has been to compile information relating to known

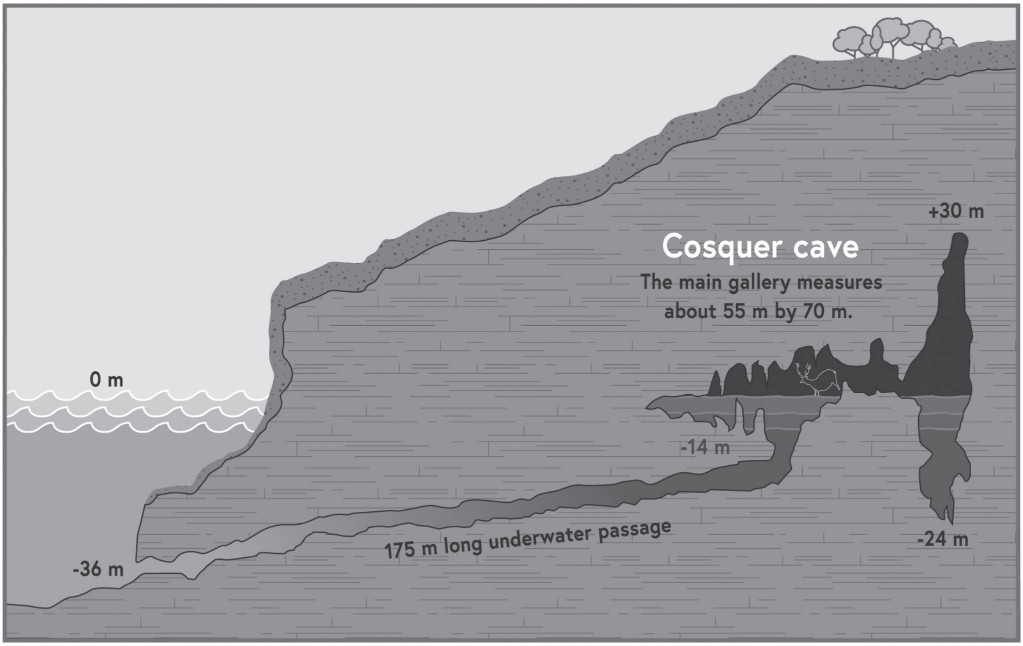

+30 m
Cosquer cave
The main gallery measures about 55 m by 70 m.
0 m
-14 m
175 m long underwater passage
-24 m
-36 m

Fig. 10.2 Cosquer Cave, France. This cross section illustrates the way in which relative sea-level has risen so that the original entrance to the cave is now submerged. Image: Rhona Jenkins

submerged and eroding archaeological sites and then make use of this in order to map inferred changes in relative sea-level around the coast (Ginesu *et al.* 2012). The remains concerned date from the late medieval period on the southwestern coast at Scivu beach, back to the Neolithic period at Grotta Verde, and they document a history of relative sea-level change around the island that is generally indicative of tilting to the east. At Grotta Verde on the west coast, for example, research on Neolithic burials recovered at a depth of 8.5 m below present sea-level within a flooded cave indicates that relative sea-levels around 7300–6700 BP lay at least 10 m below present (Antonioli *et al.* 1994).

Along the mainland coasts of France and Spain, although the SplashCos Viewer map of submerged sites in Europe (http://splashcos.maris2.nl/) notes several records of Neolithic finds along the French coast between Montpellier and Perpignan, all are unpublished. The main site on this stretch of coast is the Cosquer Cave near Marseille which dates to the Upper Palaeolithic, between 33,000 and 20,000 years ago (Clottes *et al.* 1995; Valladas *et al.* 2017). This is not a submerged site *per se*, but the entrance to the cave requires access through a 175 m long passage which is now flooded along its length and starts at a depth of 35 m below present sea-level (Fig. 10.2). Within the cave there are numerous paintings, including representations of land and sea creatures, and human hands, as well as abstract markings. The cave was discovered in 1985, and is subject to a programme of ongoing research including work on samples related to palaeoenvironmental change, radiocarbon dating and the paintings themselves (Clottes *et al.* 1997). Investigation by both archaeologists and sea-level specialists indicates that the mouth of the tunnel leading to the main chambers lay above relative sea-level at the time the paintings were created (Lambeck and Bard 2000). Indeed, the work of Lambeck and Bard suggests that a substantial expanse of land has been submerged along this coast with relative sea-level at least 50 m lower than today as far back as 50,000 years ago (2000). The original landscape within which the cave was set was thus very different from that of today. Those who lingered at the entrance would have looked out over a wide plain, though they were familiar with the coast: the animals they depicted include both land and sea species.

The coastlines of the Black Sea

The Black Sea has a complex history of change in relative sea-level, partly linked to the situation in the Mediterranean (Lericolais 2017). Research on water flow and sea-level today is very active here, with a well-developed, international, network of monitoring stations around the coast and across the basin (Goriacikin and Ivanov 2006). In general, the models suggest that relative sea-level around 18,000 years ago was at least 85 m lower than present, at which time the Black Sea was isolated from the Mediterranean and comprised fresh to brackish water. While water levels were generally rising by as much as 10 mm a year at this time, the situation is complicated by the rapid influx of brackish waters from the Caspian Sea into the Black Sea via a spillway running from the northwest of the Caspian and known as the Manych Spillway, sometime between 17,000 and 14,000 years ago due to a massive flood (Chepalyga 2007). This event raised water levels by around 60 m and led to extensive coastal flooding with a run off to the west into the Sea of Marmara (Yanko-Homback *et al.* 2011).

By about 8000 years ago, relative sea-level in the Black Sea lay some 25 m below present levels and continued to rise (Goriacikin and Ivanov 2006), but research indicates another catastrophic inundation around 8400–7200 years ago when saline waters from the Mediterranean entered the Black Sea via the Sea of Marmara (Ryan *et al.* 1997). The identification and interpretation of this flooding event remain controversial. From the start, it has been obscured by allusions to the Biblical flood and referred to in the popular press as ‘Noah’s Flood’ (Wilford 1996) or the ‘Great Flood’, while there was some scepticism about the fact that previous research had apparently missed the evidence (Ryan 2007). Ryan considers that it is not so much a question of missing the signs as of how they were interpreted. The research focusses on both the physical features: ancient shorelines and the topography between the Black Sea and the Mediterranean, and on the water conditions: salinity levels in the Black Sea as evidenced by ancient molluscs and stable isotopes. Using Bayesian modelling, applied to redating of molluscs within the sediments Turney and Brown postulate a more precise date for the flooding event to between 8350 and 8230 years ago and they link it to the sudden rise in global sea-levels with the collapse of the Laurentide Ice Sheet and outflow from Lake Agassiz around 8400 years ago (Turney and Brown 2007), though Yanko-Homback *et al.* (2011) remain sceptical. Other interpretations of the evidence include a more gradual rise in relative sea-level (Giosan *et al.* 2009) while Yanko-Hombach and colleagues also postulate oscillating relative sea-levels in the last 10,000 years (2011). The controversy continues, Yanchilina and colleagues combine a wide range of geoscience techniques to provide new data that they interpret as supportive of a substantial terrestrial landscape between the Mediterranean and the Black Sea prior to the influx of saline water to the basin (Yanchilina *et al.* 2017). They suggest that the level of the Black Sea had fallen to some 120 m below present water levels at this point and that the influx of Mediterranean waters across the shelf was catastrophic and led to rapid salinification. No doubt the research, and the debate, will continue.

Whatever the precise explanation for the transformation that has taken place in the Black Sea since the Last Glacial Maximum, it is clear that there has been considerable change in the amount of land available and topographical conditions around the sea (particularly in the north on either side of the Crimean Peninsula), and in the water, and therefore related environmental, conditions. These changes must have impacted on the lives of those who lived in this part of the world. With regard to relatively recent times, the original research publication on the possible Holocene flooding event made the suggestion that it might be linked to the apparently rapid spread of farming along the rivers and coasts of Eastern Europe away from the Black Sea (Ryan *et al.* 1997). More anecdotally, others suggested that it might have given rise to the mythology of Gilgamesh and Noah. With regard to earlier times, finds on land indicate the presence of Palaeolithic and Mesolithic populations in the area (Stanko 2007). The rich archaeological record of the surrounding countries suggests that a significant underwater resource might be expected in the waters of the Black Sea and the extent of environmental change triggered by the hypothesised flooding events opens the possibility that community movements, perhaps even migrations, might have been triggered. These are clearly of potential significance with regard to the early peopling of Europe and changes to the economy at various times so that it becomes important to understand the nature of the archaeological resource in the area.

At the time of writing, precise information related to submerged sites in the Black Sea is limited. Stanko notes finds of unspecific (possibly Palaeolithic) stone tools from the Black Sea shelf to the west of Crimea (2007), while Filipova-Marinova and colleagues discuss Neolithic and Bronze Age remains along the Bulgarian coasts and use the analysis of sediments from lacustrine and marine cores to provide environmental context (Filipova-Marinova *et al.* 2011). One site that has received detailed investigation is an Early Bronze Age pile-dwelling lying about 6 m below sea-level in Alepu lagoon, Sozopol, on the coast of Bulgaria (Flaux *et al.* 2016). This work has involved mainly environmental sampling, allowing a detailed reconstruction of both the environment and the economy of an occupation along the shore that has been dated to 5350–5000 BP. Around the shores of Lake Varna, the traces of at least 13 submerged prehistoric settlements have been recorded, though few have been excavated (Peev 2004). Many of the sites have organic materials and Peev suggests that the construction methods included the use of massive timber foundation beams. Although the sites lie in coastal situations, reconstruction of the ancient environment indicates that all occupy sheltered riverine terraces that would have been set back from the sea itself (Peev 2004; Flaux *et al.* 2016). Filipova-Marinova and colleagues suggest that this was, in general, a forested landscape (2011) with evidence indicative of the impact of the human communities on the environment, including the cultivation of crops and forest clearance for agriculture and domestic animals. Flaux and colleagues comment on the abundance and significance of fish and shellfish in addition to terrestrial resources and they note the possibility of the preservation, and even trade, of preserved marine foods (2016).

In contrast to the sites described above, Yanko-Homback *et al.* suggest that much of the northern coastal plain of the Black Sea, around the Crimea, was marshy and mosquito infested in the Early Holocene (2011). The environmental details relating to the formation of the Black Sea may remain controversial (and the cynical may note a certain element of national rivalry here), but it is clear that the continental shelf in the area holds considerable potential for archaeology. Extensive tracts of land have been submerged since the Last Glacial Maximum and into the Early Holocene, preservation conditions are good, and the terrestrial archaeology of the region suggests that this may have been a pivotal area for both Palaeolithic and Neolithic communities. Yanko-Hombach and colleagues identify the northwestern shelf as the most likely to reward prospection for submerged archaeological material (Yanko-Hombach *et al.* 2017). Caraivan and others discuss the potential of the Romanian coast (Caraican *et al.* 2017). The resource continues into the Sea of Marmara where hints of submerged sites have been recorded and excavations under Istanbul have recovered the remains of a substantial Neolithic settlement at Yenikapi (Selkirk 2013).

11. Submerged landscapes around the world: Atlantic and Northwest Europe

Atlantic coasts of mainland Europe

Iberian Peninsula

At the southern tip of Atlantic Europe lies the rock of Gibraltar which investigation shows to have been surrounded by a plain extending for some 20 km when relative sea-level dropped at various times in the past. Fa and colleagues note that in the period from 65,000 years ago the human groups that occupied the caves of present day Gibraltar had access to a variety of ecosystems, across savannah-type grassland to coastal estuaries, wetlands and bluffs. This plain disappeared in the Holocene and is currently under investigation, both to shed light on the nature of the landscape and palaeoenvironment and regarding the possibility that submerged archaeological deposits may survive in underwater caves and other locations (Fa *et al.* 2001; Canals *et al.* 2017). Interestingly, marine shells and fish bones have been found within the existing Neanderthal deposits from the Gibraltar caves that lie above present sea-level, though the coast would have been a few kilometres away (Finlayson *et al.* 1998; Brown *et al.* 2011).

While submergence has taken place along the Portuguese coast since the Last Glacial Maximum, resulting in the inundation of areas of the continental shelf likely to have been exploited for Palaeolithic settlement, episodes of uplift have also occurred, so that in some places, Pleistocene coastal deposits have been recorded inland (Haws *et al.* 2011). Published investigation of submerged landscapes is lacking here, nevertheless, a number of activity sites relating to the exploitation of coastal resources and locations during the Palaeolithic have been revealed, at varying heights on shoreline terraces and along the present cliff lines (Haws *et al.* 2010; 2011). At Praia Rej Cortiço, a Middle Palaeolithic site comprising stone tools together with organic deposits containing charcoal has been excavated at the back of the present beach, below an eroding coastal bluff. Thick peat deposits to one side of the site suggest that it was originally located within an area of marshlands and tidal flats (Haws *et al.* 2010).

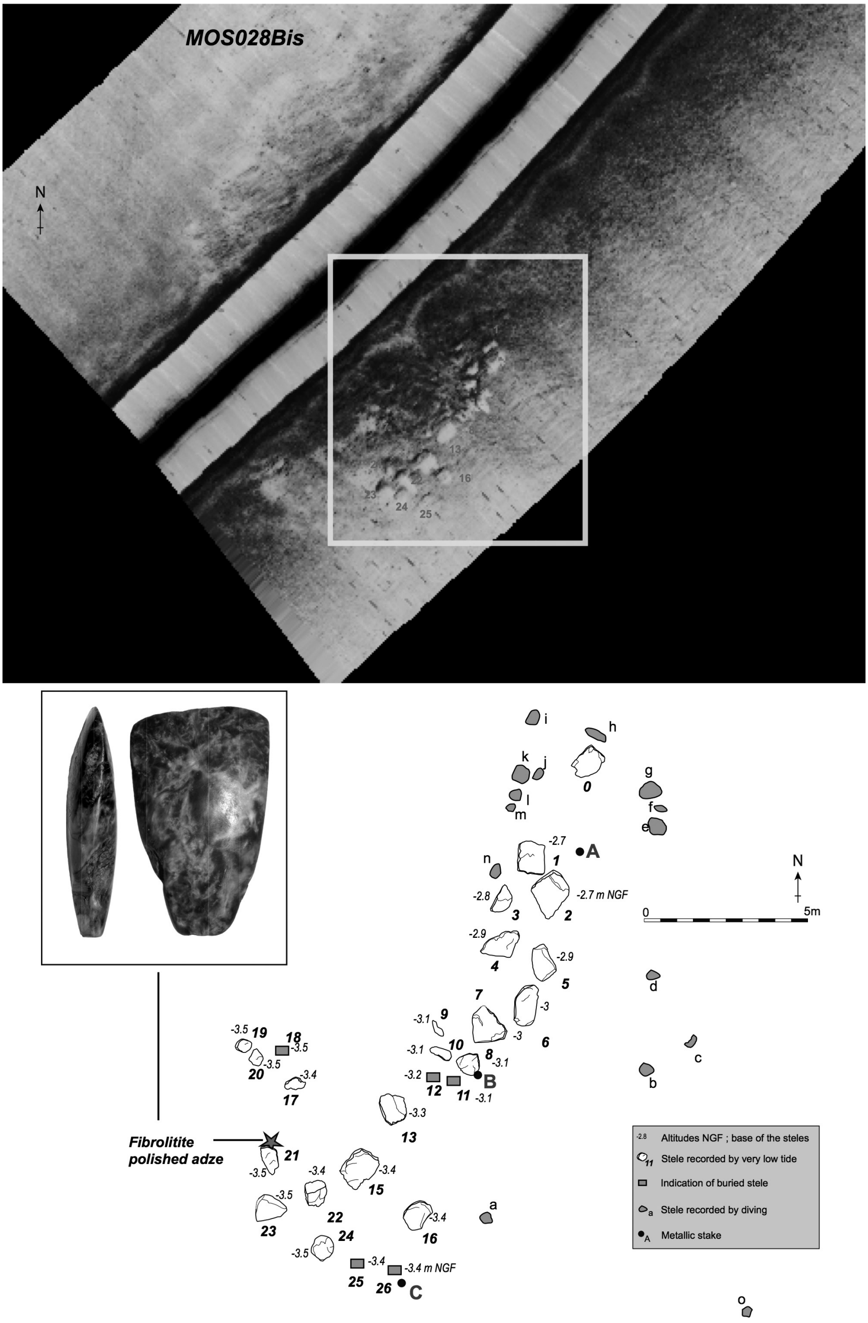
France and the Channel Islands

In contrast to the Iberian Peninsula, many submerged archaeological sites have been recorded along the Atlantic coasts of France, but, few have been published. Most of the dated material has been referenced using typological dating and (perhaps not surprisingly), is quoted as of Palaeolithic (a few sites), or Neolithic (most sites) date while several locations remain of unspecified prehistoric date. The distribution of find spots may be seen on the SplashCos viewer (http://splashcos.maris2.nl/). This suggests that a considerable archaeological resource lies off the coasts of France, but detailed investigation is necessary in order to assess the survival and significance of individual sites.

One focus where investigation has taken place lies in the Morbihan, on the south coast of Brittany, which is known for the Neolithic stone rows at Carnac. This area has undergone considerable submergence in the Early Holocene with a dramatic impact on the landscape which has evolved from a broad coastal plain with elements of high ground around 11,000 BP, to an indented landscape with deep, inset bays, the mouths of which are sheltered today by a series of rocky islands (Daire 2009; Daire *et al.* 2014). Recent archaeological research here has focussed on the submerged landscape around the Quiberon peninsula, in order to assess the possibility that the megalithic sites may have extended across a wider area than that now delimited on land. A strong clue is provided by the stone settings of the island of Er Lannic, at the entrance to the Golfe du Morbihan, which may be seen to run underwater (Pl. 4), submerged by Holocene rises in relative sea-level (Large and Mens 2015). At St-Pierre-Quiberon, some 18 km to the west of Er Lannic, Cassen and his colleagues have been using sidescan sonar survey in the nearshore zone in order to investigate parallel rows of low monoliths that have been recorded at low tide (Cassen *et al.* 2011). This work is still largely experimental, but it yielded positive results relating to the mapping of the monuments as they run out to sea (Fig. 11.1). The sonar survey was followed up with diver survey in order to clarify the nature of the anomalies recorded and, in this way, it was possible to identify a series of stone settings on the seabed which have survived submergence. This work is strongly indicative that the sites recorded on land do not present the whole picture of the Neolithic monuments of the region and that further investigation of the drowned landscape here is necessary in order to understand fully the stone alignments and prehistoric monuments around ancient Carnac.

A frequently recorded site type in France comprises ancient fish-traps, often built of stone within the intertidal zone and sometimes incorporating natural rock outcrops in their structure. In their summary of the known sites of Brittany, Langouët and Daire note the various methods of construction of 570 trap sites (2009). While many date to the historic period, others go back to the Bronze Age, and a few may date as early as the Mesolithic. In common with other coastal sites, fish-traps are impacted by relative sea-level rise and as such their place in the archaeology of the submerged landscape should not be forgotten.

To the north of the Brittany coast lie the Channel Islands, once part of the Channel Plain, an extensive prehistoric landscape that joined the islands to the Continent. The archaeological sites of the islands provide evidence for thriving communities as far back as the late Middle Pleistocene, at La Cotte de St Brelade a Neanderthal site with intermittent occupation evidence for the period between *c.* 238,000 years ago and 40,000 years ago (Callow and Cornford 1986). Archaeological research in the islands has focussed on terrestrial sites, but with an increasing emphasis in recent years upon the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Indication of buried stele
a Stele recorded by diving
A Metallic stake

Fig. 11.1 Petit Rohu, the stone row captured in a sidescan image and as planned, together with the Neolithic axe found towards the southern end of the setting. Images: S. Cassen, Sonogram S. Cassen and A. Lorin

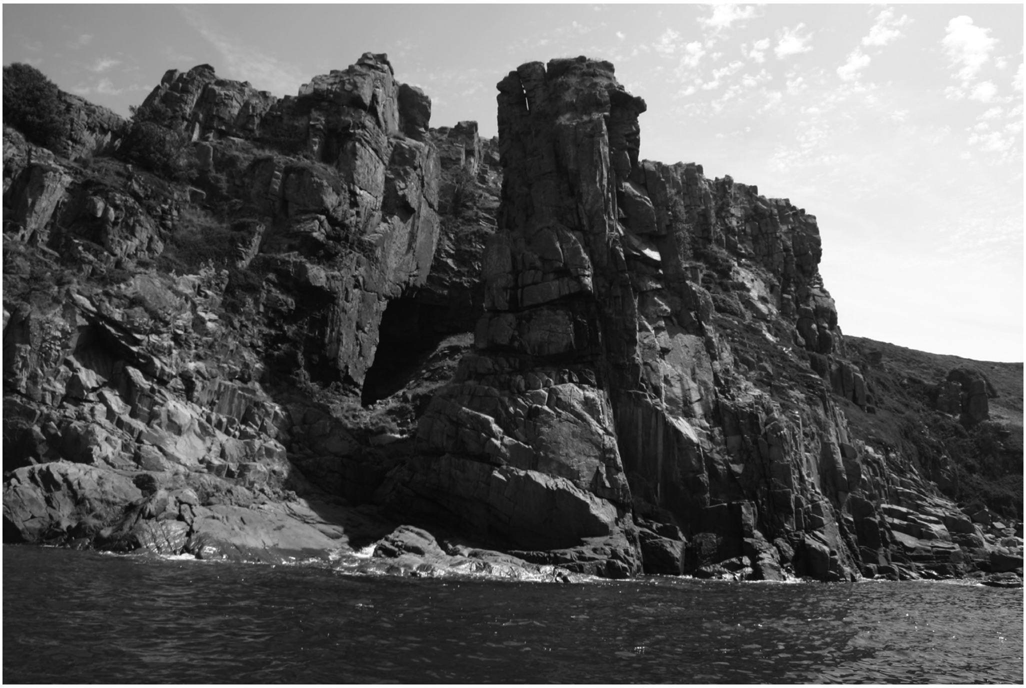


Fig. 11.2 The entrance to the cave at La Cotte, Jersey, may be seen among the spectacular rocky cliffs at the site. Image: Martin Bates, University of Wales, Trinity St David

way in which the location of the islands as upstanding elements of a wider terrestrial plain alters our understanding of the activities undertaken by the earliest prehistoric communities here. Interestingly, this has produced significant results at two very different scales: the local landscape around a site; and the wider territory that would have been available to the mobile groups of hunter-gatherers at different times.

La Cotte de St Brelade (Fig. 11.2) was originally excavated in the 1960s and 1970s, and interpreted, on the basis of extensive deposits of mammoth bone, as the location of a kill site where mammoth were driven over a natural cliff by Neanderthal groups. In common with the accepted wisdom of the day, this interpretation rested on the assumption that the landscape during the time of occupation resembled that of today (Callow and Cornford 1986). Recent investigation at the site (Bates *et al.* 2013b), undertaken as part of the Ice Age Jersey Project (https://www.jerseyheritage.org/ice-age-island/the-ice-age-project), has incorporated the new understandings of past relative sea-level change to include high resolution bathymetric survey with sidescan sonar which has helped to place the site into a more accurate contemporary landscape setting. In particular, the project is interested in the periods of lowered relative sea-levels when Jersey would have been part of a wider landscape (Scott *et al.* 2014). By including the wider local topography of the site, it has been possible to suggest that the Neanderthal occupants visited repeatedly over a period of at least 150,000 years, during which there were, undoubtedly, local changes in climate and landscape. Significantly, one attraction of the locale seems to be the way in which, at times of lower relative sea-level, it provided views across an extensive hunting ground, occupied by mammoth, horse, bison and rhinocerous. Immediately below the site, which would have been set into the rising cliffs of a plateau that projected above the floor of the plains, a blind valley provided an ideal setting for a rather different type of kill site to that proposed by the original work (Pl. 42). The research suggests that game, such as mammoth, could, at least at some periods, have been driven into this valley where they would be vulnerable to human predators.

Another aspect of the research focusses on the acquisition of raw materials for stone tools from the landscape around the site (Shaw *et al.* 2016). The material within the cave at La Cotte de St Brelade indicates repeated periods of activity by Neanderthal groups, some long-term and others more transient. Through time, a variety of raw materials was collected and brought to site, from different sources up to 20 km away. These raw materials were treated very differently, depending on both their origin and the duration of activity on site. Flint, and other stone from further away, often arrived on site as pre-existing tools and was carefully curated and reworked in order to make the most of precious resources. Much of this took place during short-lived, transient, occupations of the site. In other periods, however, the occupants of the cave found it necessary to collect different materials, from closer to the site. This material was roughly shaped at the source, but most of the toolmaking was done on site. It seems, however, that the more local materials were less carefully curated, perhaps due to the relative ease of acquisition, and that knapping techniques employed on local stone were more expedient. The authors suggest that the site at La Cotte de St Brelade (which is still impressive today) was a location of such significance that Neanderthal groups chose to return over thousands of years, even given different local conditions and access to raw materials.

The research on the Palaeolithic occupation of La Cotte is a fantastic example of the significance of the submerged landscape. Despite the lack of specific archaeological sites on that landscape, the presence of human groups moving through it has been unpicked by the research and it has helped to place the terrestrial site itself within a more complete prehistoric setting. Further work has focussed on the Mesolithic occupation of the Channel Islands as a whole (Conneller *et al.* 2016). Though Conneller and colleagues base their research on terrestrial sites, they, too, note that lower relative sea-levels have had an impact on the past topography of the island archipelago. As relative sea-level was steadily rising by the Mesolithic, there is also an element of change, and the human perception of change, in the landscape that is important to consider in order to understand the wider context of human activity. In particular the impact of different models of relative sea-level change (given the lack of actual data) is noted, each of which postulates a different date for the severing of specific islands from the larger landmass.

Around the coasts of Normandy, France, to the east of Cherbourg, investigation of the seabed at a depth of about 20 m below present sea-level as part of the project: Les Premiers Hommes en Normandie, has revealed a series of Middle Palaeolithic sites including worked flints, hearths and environmental material (Cliquet *et al.* 2011). The archaeology here was first recorded in a submerged peat deposit in the 1970s (Cliquet 1994), but detailed investigation has only been possible with the development of more refined marine technologies in more recent decades. There is an interesting submerged landscape here, comprising a substantial cliff face, at the foot of which a number of rockshelters and caves were made use of by Palaeolithic communities. The team have undertaken some detailed analysis of the palaeoenvironmental evidence around one of the sites, at La Mondrée, which not only provides a nice context for the site (at the edge of coastal wetlands), but also suggests that this activity took place between 130,000–80,000 years ago, during an interglacial, known in the UK as the Ipswichian, and elsewhere as the Eemian. In addition to seismic survey and related sediment coring, the new work has included diving survey which revealed the existence of additional lithic material eroding out on the present seabed and a small test excavation was also undertaken, using suction devices as well as by hand. Post-excavation analysis has included technological and typological work on the lithics and a detailed study of the raw materials and their likely provenance. In 2011, it was noted that the full extent of the site had yet to be uncovered and, while other submerged collections of Palaeolithic artefacts around the peninsula are noted on the SplashCos Viewer, none has been recorded in detail.

The combined impact of the work in the Channel Islands with that in Normandy is to highlight the significance of the Channel Plain during the last (Ipswichian) interglacial as a productive environment for the Middle Palaeolithic populations of the time. Communities clearly ranged across it, well able to find food and other resources such as raw materials for their stone tools. It is a good example of the way in which the landscape of today is transient.

Belgium

Not surprisingly, awareness of the potential of the submerged landscape is not lacking in Belgium, yet, despite considerable commercial development impacting on the seabed, few sites have been recorded. This situation is being remedied with the publication of key sites, and development of the SeArch project to provide guidance on standards and promote awareness (Missiaen *et al.* 2017). Through the promotion of these guidelines for research and management, it is hoped to encourage the investigation of underwater sites here.

Raversijde Beach, to the west of the centre of Ostend was chosen for study, on the basis of a history of relative sea-level rise that had resulted in the documented loss of a historical village, the settlement of Walraversijde, in the 15th century. In addition, finds of archaeological material including Palaeolithic stone tools have been made on the beach, while a wooden paddle dated to prehistory (Neolithic to Iron Age), was recovered from the intertidal peats (Pieters *et al.* 2010). Work included a number of different remote sensing techniques and palaeoenvironmental analysis (Missiaen *et al.* 2014; Missiaen 2015) and has resulted in the detailed reconstruction of the evolution of the landscape as well as the identification of possible areas of human activity.

The Netherlands

Detail relating to submerged archaeology increases as one moves north into the Netherlands, where the early recognition by archaeologists of the existence and potential value of the submerged landscape (Louwe Koojimans 1971), has been combined with active liaison with the commercial fishing community to ensure that finds of relevance to the past environment of the North Sea are recognised and retrieved (Glimmerveen *et al.* 2004). Interestingly, in the Netherlands the study of submerged landscapes includes the offshore zone, as well as inshore and coastal sites (Verhart 2004). Although this might seem an obvious element of research, few countries have extended their investigations to include deeper waters.

The presence of ancient material on the floor of the Dutch sector of the North Sea, including both animal and human remains, as well as stone and other artefacts, has been recognised for many years (Cohen *et al.* 2017). Carefully nurtured liaison with the fishing industry has resulted in the recovery of a large body of material (Glimmerveen *et al.* 2004) and investigation of the changing landscape continues to produce detail of the varied topography and environmental settings as the landscapes evolved from the Pleistocene into the Holocene. Several authors comment on the lack of information relating to the past vegetation of the submerged landscapes of the North Sea continental shelf; it seems that research has focussed on the application of more recently developed geoscience techniques to the detriment of traditional information sources (Peeters and Cohen 2014).

Cohen and colleagues (2017), note that, as most of the animal and human finds are recovered from the sea floor where they have little preserved context, it can be hard to relate them to specific landscapes or environments, but the assemblage as a whole provides a considerable resource and ongoing investigation continues to refine the detail (Vos *et al.* 2014). While the archaeology of submerged landscapes is, in many places, generally associated with Mesolithic activity (Figs 11.3 and 11.4), Peeters and Momber point out that the drowning of the North Sea has also impacted on understanding of the Upper Palaeolithic settlement of the area (Peeters and Momber 2014). Interpretation of the lifestyles and interaction of groups such as the Magdalenian, Cresswellian and Hamburgian communities of northwest Europe has, until recently, been very dependent on information relating to an incomplete view of their landscapes derived from terrestrial archaeology. It is worth noting that as early as 1991, Jacobi commented on the likely significance of the submerged landscape of the North Sea for human settlement at this time (Jacobi 1991). Curiously, Late Palaeolithic material is rare among dated finds from the North Sea (whether by typology or absolute dating), though the explanation for this, and its resulting significance, have yet to be elucidated. There is certainly evidence for Late Palaeolithic activity on either side of the North Sea (including emerging evidence in Scotland; Ballin and Wickham-Jones 2017), which is suggestive of some presence on the landscapes between. One explanation may lie in the erosion of relevant sediments (Peeters and Momber 2014).

Closer to the Dutch coast, work on commercial projects such as the maintenance and development of the Europoort at Rotterdam integrates archaeology and geology and has resulted in the recovery of considerable quantities of artefacts of Mesolithic and

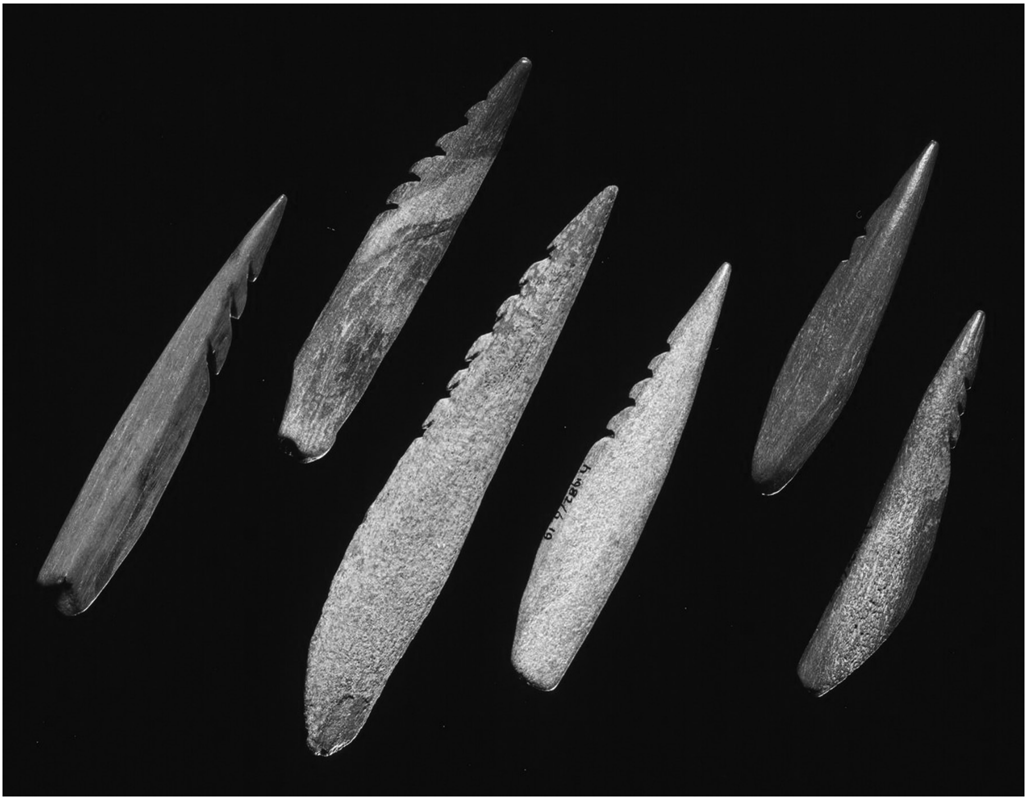


Fig. 11.3 Bone and antler points recovered from the bed of the North Sea (c. 10,000–8000 cal BP). Image: National Museum of Antiquities (RMO), Leiden, the Netherlands

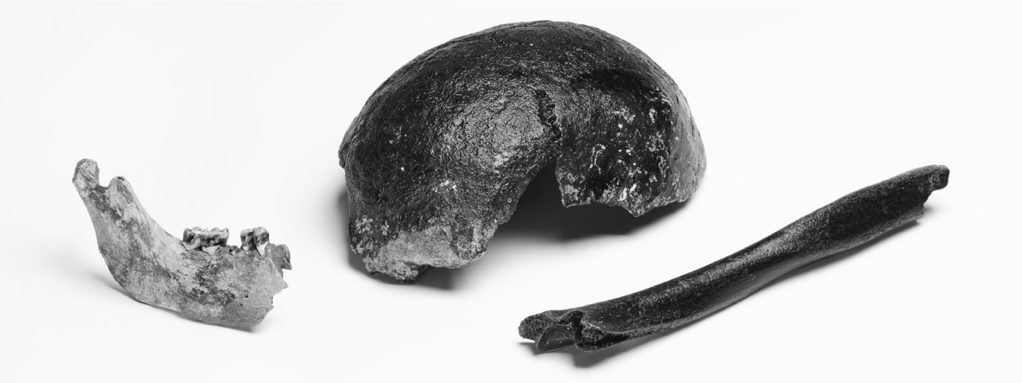


Fig. 11.4 Human (Homo sapiens) skeletal material recovered from the bed of the North Sea (found in fishing nets and on the beaches) dating to the Mesolithic (c. 11,000–8,000 cal BP). Image: National Museum of Antiquities (RMO), Leiden, the Netherlands

earlier date (Peeters and Momber 2014). The recovery of finds here goes back several decades (Louwe Kooijmans 1971), and, while the date and contemporary field practices mean that much of the material is not associated with *in situ* contextual information, more recent projects have resulted in detailed investigations of the palaeolandscape. At sites like that of the Yangtze Harbour, in the Maasvlakte area, geoscience investigation has integrated seismic survey with coring and sediment analysis to reveal a well-developed system of river dunes bordering a floodplain within which human movement is likely to have been facilitated. This work culminated with archaeological excavation conducted from a pontoon, providing a good example of the possibilities where finance and inclination were available (Pl. 43). During excavation, material was extracted as grab samples using a crane, and then sieved before being sorted by hand (see Fig. 8.2) (Kubiak-Martens *et al.* 2013; Zeiler 2012). Finds included lithic tools (see Fig. 8.3) and debris, bone fragments, charcoal samples and plant remains. This has allowed a detailed reconstruction of the site and surrounding area from the Mesolithic to the medieval period (Vos *et al.* 2014). The work at the Yangtze Harbour is significant, not only for its results in terms of understanding of the Early Holocene communities of the area, but also in terms of its contribution to the management regimes of both this and other areas (Ward *et al.* 2014). The depth of the excavation work, reaching up to twenty metres deep (Sier *et al.* 2014), might have been regarded as off-putting by many projects; the recovery of useful information here is promising for work elsewhere.

Not only does investigation of submerged sites and landscapes in the Netherlands extend further offshore than is usual, it is also integrated with the terrestrial archaeology in a way that rarely occurs elsewhere in Europe. The Netherlands has an active history of prehistoric research on land, including much work among wetlands and on waterlogged sites, even away from the sea and this has, not surprisingly, been instrumental in shaping attitudes to the interplay of archaeology and watery environments.

Germany

Along the Atlantic coasts of Germany information relating to the submerged landscape focusses around the Wadden Sea and in particular three National Parks: The Schleswig-Holstein Wadden Sea National Park; The Hamburg Wadden Sea National Park; and The Niedersaechsisches Wattenmeer National Park. Collections of finds, mainly undated, and usually unstratified, but including Mesolithic and Neolithic material, have been recorded from each area, in particular among the offshore islands.

The Wadden Sea comprises the largest area of tidal flats in the world and, as such, it provides a shifting area of soft sediments under relatively shallow waters, up to 10 m deep, overlying the submerged landscape of the Late Pleistocene and Early Holocene. The evidence suggests that the Wadden Sea started to emerge in the early millennia after the end of the last Ice Age due to the interplay between relative sea-level rise, varying tidal range, marine currents, plankton and other biomass, and the supply of sediment towards the coast from the drowning landmass of Doggerland (Reise 2013). This is not a stable landscape, islands come and go, and sediment analysis has revealed the presence of successive land surfaces alternating with marine deposits (Bazelmans *et al.*

2012). Local conditions, including the topography of existing islands and dune systems mean that there is no uniform sea-level curve for the Wadden Sea as temporary offshore barriers have played a considerable role in holding back inundation in some areas while allowing it in others. At times therefore, considerable dryland landscape areas have existed here, albeit never permanent. These shifting land surfaces have been recorded into relatively recent times, for example around the island of Pellworm where shifting tidal channels in 2011 revealed an expanse of drowned medieval fields. In addition to the existence of dry-land sites, specific adaptations to the marshy, shifting, landscape here included the construction of dwelling mounds from around 600 BC (Nieuwhof *et al.* 2013), and the digging of drainage ditches. Remnants of this landscape may be picked out on Google satellite imagery (Pl. 44), and a recent paper has highlighted the

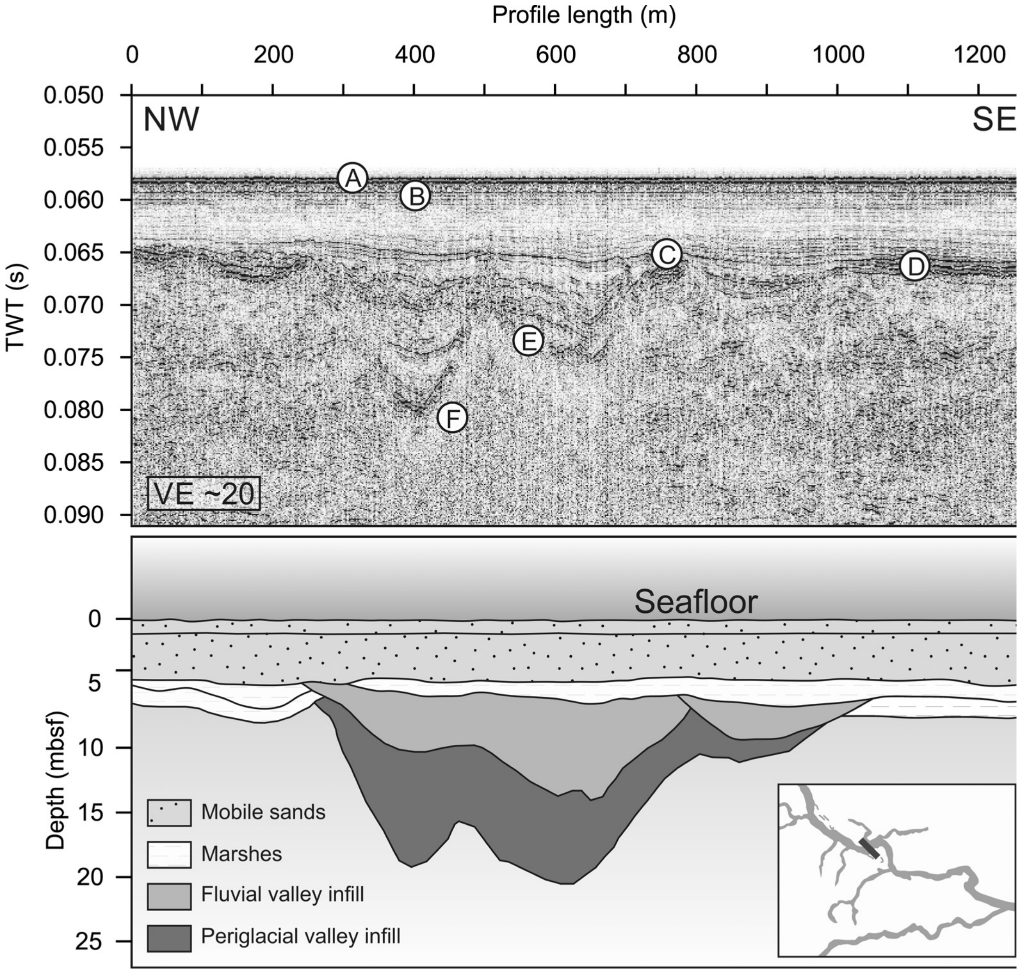


Fig. 11.5 Palaeo Elbe research. Seismic cross section and interpretation. From Hepp et al. (2017)

value of high-resolution space-borne synthetic aperture radar for survey work in fragile intertidal flats such as this, which can be hard to access (Gade *et al.* 2017).

In 2012, a project was set up to record the archaeological finds of the Lower Saxony Wadden Sea area in Germany (Jöns *et al.* 2013). In order to provide some palaeoenvironmental context for the archaeology, information from existing sediment cores and seismic profiles is integrated into a palaeogeographic study of the area and its development over time (Karle and Goldhammer 2017). In this way, it has been possible to build a reconstruction of the shifting landscape through time and, by identifying possible areas of settlement and preservation, a management tool has been created with the potential to facilitate both the care and the understanding of the area (see Fig. 8.1).

In the deeper waters of the North Sea, out towards Dogger Bank, German research has focussed on the reconstruction of the submerged landscape of Doggerland. Using seismic survey, Hepp and colleagues have been able to identify topographical detail relating to two ancient river systems flowing south and west from Doggerland into the palaeovalley of the River Elbe (Fig. 11.5). The lack of sediment analysis means that it was not possible to date these river systems, but considerable change over time, likely to be from the Late Glacial into the Early Holocene, was shown (Hepp *et al.* 2017). Although no archaeological remains were identified, this is an important contribution to the growing body of knowledge on Doggerland and the changing landscape occupied by the hunter-gatherers of North West Europe at the end of the last Ice Age.

Scandinavia and the Baltic

Denmark

The coastal seas of Denmark were, largely, dry land through the Mesolithic and, in places, into the Bronze Age. At the mouth of the Baltic, generally low-energy waters facilitate both the preservation and study of these submerged landscapes and archaeological sites. In many ways, the discipline of submerged landscape studies was developed here, and a glance at any global map of sites will reveal a plethora of sites in Danish waters (Fischer and Petersen 2018). This includes the coastlines of the North Sea, though detailed work has focussed on the Baltic shores. Increasing awareness of the possibilities of submerged sites in Danish waters meant that archaeological material was recognised by a wide variety of people, including recreational and sport divers, and the first systematic studies were underway by the 1970s (Grøn 1995; Skaarup 1995). By 1998, over 2300 sites and find spots had been recorded around the coasts of Denmark (Fischer 2004), and ongoing research continues to add to the record. Despite the existence of well-preserved archaeological sites on land, Denmark, more than any other country, perhaps exemplifies the way in which research on submerged archaeology can enhance understanding of past, in particular of prehistoric, populations. Nevertheless, Danish waters are busy waters and so it was necessary to develop strategies to locate and manage the underwater sites. As a result of this, the 'Fishing Site Location Model' was developed by Fischer using information from traditional fishermen and combining it with information about the ancient landscape (Fischer 1995a). This model has since

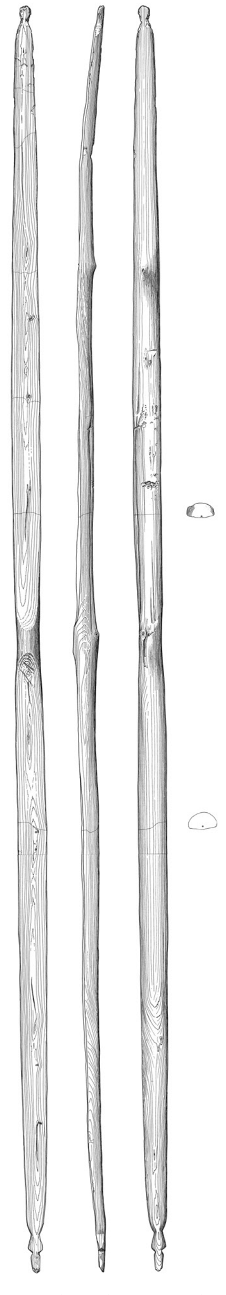


Fig. 11.6 Tybrind Vig, Denmark, a complete bow made of elm. It measures c. 1.67 m long, the central grip may be seen, together with nocks for attaching the strings at each end. Image: Moesgaard Museum, National Museum of Denmark, Jutland Archaeological Society. Courtesy, Søren Andersen

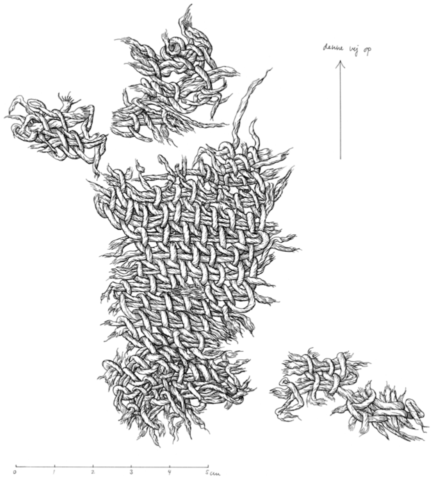


Fig. 11.7 Tybrind Vig, Denmark, preserved textile fragments, the largest piece measures about 50 × 75 mm. Image: E. Morville, Moesgaard Museum, National Museum of Denmark, Jutland Archaeological Society. Courtesy, Søren Andersen

been deployed very successfully to locate sites in Danish waters, with the dual aims of investigation and management as appropriate.

The success of the Fishing Site Model has led to attempts to refine it for deployment elsewhere around the world (Benjamin 2010; Hall 2014), but it has also been critiqued (Grøn 2015), not least because of the lack of testing of the null hypothesis and the way in which it can reinforce stereotypical ideas of site location. While there are certainly weaknesses to the model, it is worth noting that the figure quoted by Grøn relating to the number of sites recorded underwater, 0.05 per km^2, even if minimal, is still impressive in comparison with the results of underwater surveys in many other places. It is likely, however, that this relates as much to the specific conditions in Danish waters as to the application of the model itself.

The value of the Danish work has, thus, been to demonstrate the potential of the submerged archaeological landscape. This has included both 'rescue' and research archaeology. In 1997, the publication of several years' work on the submerged landscape of the sound known today as the Storebælt, in advance of construction work, highlighted the way in which the investigation of individual sites could build into an understanding of the use of the landscape from the Mesolithic to the present day (Pedersen *et al.* 1997). Elsewhere in Denmark, perhaps the best-known individual site is that of the settlement at Tybrind Vig, where a long history of investigation and publication spanning three decades has brought to light well-preserved finds (Figs 11.6 and 11.7) including pottery, textiles and netting, canoes, paddles, and graves, all dated to 7400–6000 BP (Andersen 1985; 2011; Uldum 2011). The excavation of Tybrind Vig pioneered many of the techniques for recovering information from submerged sites, and has amplified knowledge of Mesolithic life in surprising ways (Malm 1995). While the existence of boats, and paddles, might have been assumed from settlements on islands, only the excavation of preserved material could have illustrated the way in which artefacts such as paddles were decorated (Andersen 2011). Similar artefacts to those from Tybrind Vig have now been discovered from other submerged sites such as Satrup (Hartz and Lübke 2000), and Ronaes Skov (Andersen 2009). Pioneering excavation work continues at Tybrind Vig: in 2007 and 2008 further burials were excavated by an international team of divers from Denmark and Norway (Uldum 2011).

Ongoing work elsewhere in Denmark continues to monitor sites and includes some excavation, for example at the site of Hjarnø Sund, first recorded in 1957, but recently investigated due to erosion (Skriver *et al.* 2017). Research here has included excavation with an induction dredge as well as intensive core sampling. The submerged remains comprise two shell middens together with finds including organic materials as well as stone tools (Pl. 29b and Fig. 11.8). Radiocarbon dates place the activity around 6700–6540 BP.

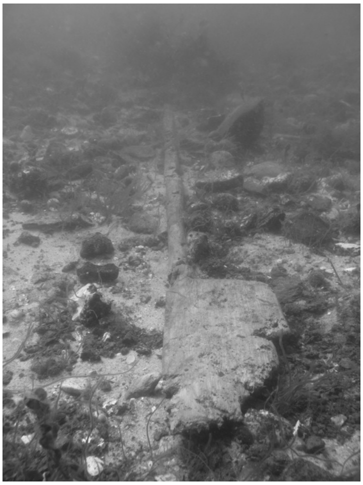


Fig. 11.8 Harnø Sund, Denmark: A wooden paddle lying on the eroding seabed surface. Image: Peter M. Astrup. From Skriver et al. (2017)

Baltic Germany

Research to locate submerged sites and landscapes along the Baltic coast of Germany took off in 1998, drawing on the experience of Danish colleagues and others (Lübke *et al.* 2011). The landscape history of this coastline reflects the changing conditions within the Baltic and the work was set up as an interdisciplinary project to examine changes in relative sea-level, palaeogeography, and archaeology. Sonar survey, combined with remote video observation, sediment sampling, and diver survey has resulted in the location of several sites. Key sites were then investigated in greater detail by excavation, using induction dredges. Finds include stone tools, hearth sites, and organic materials and, in general, the sites span the period 8500–6700 BP. In addition to the archaeological work, research has focussed on the development of the environment using material such as ancient timbers, deposits of peat, and preserved hazelnuts.

In Kiel Bay, the Strande site LA163, was recognised by divers in 2011 and subsequently investigated by excavation and sediment sampling. The results indicate a Mesolithic settlement site with ample evidence for a variety of activities and exploitation of different habitats, including land and sea, dating to 7450–6750 BP (Goldhammer and Hartz 2017). The site was particularly rich, and finds included wooden objects such as fishing gear, stone tools, human bones, and environmental material including hazelnut shells as well as well-preserved tree trunks (Pl. 29a). Further work was done to explore the extent of the site and nature of the sediments. Further into Kiel Bay, the examination of submerged tree remains undertaken in advance of the extension of the ferry terminal at Kiel-Friedrichsort has provided information relating to the existence of an alder wood dating to around 7200–7000 BP (Feulner 2017), thus adding to the interpretation of the development of the palaeoenvironment.

In Weismar Bay, around the Jäckelberg Reef it has been possible to build a detailed picture of the changing landscape here, from a freshwater environment through a fjord-type landscape to the marine embayment of today (Lübke et al. 2011). Throughout that time, people have made use of the area, adapting their lifestyle to make the most of available resources, and several sites have been examined in more detail. It is a good example of the benefits of detailed, targeted research and of the potential of the submerged landscape. While it is not possible to study every coastline in this detail, nor are sites and organic deposits always preserved, yet it is important to build a good idea of the potential resource and of the material that we are losing where research conditions are not so good.

Poland

The history of relative sea-level of the Baltic means that the submerged landscapes of the Early Holocene only exist along the southernmost shores (Fig. 11.9) (Harff *et al.* 2017) and less research has been undertaken towards the east. A double-barbed harpoon of reindeer antler from the sea floor to the north of Dziwnów was noted by Janowska (1995), but to date there has been little discussion of actual sites and the way in which the offshore landscape would have contributed to the world of the Early Holocene. Uścinowicz and colleagues discuss the implications of submerged forest remains located in Gdansk Bay (Uścinowicz *et al.* 2011) and other examples are noted by Rosentau and colleagues who also record examples as far east as Lithuania (Rosentau *et al.* 2017).

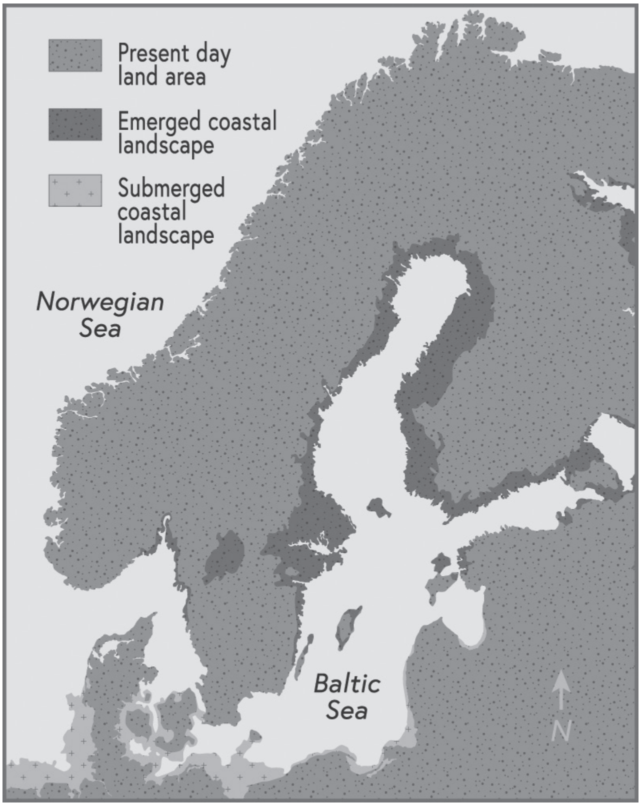


Fig. 11.9 In the Baltic submerged landscapes only exist along the southern shores. Relative sea-level fall in the northern Baltic means that old shorelines now lie above present-day sea-level. Image: Rhona Jenkins

Despite areas of high energy waters, low energy coastlines and areas of sedimentation also exist here (albeit sedimentation can serve to mask the archaeology), and it is surely only a matter of time before prehistoric sites are recognised in this section of the Baltic. Studies on land reinforce the value of coastal resources here in the Early Holocene.

Sweden

Study of the submerged landscape has a long history in the south of Sweden where the post-glacial development of the landscape between Denmark and Sweden played a crucial role in the development of the Baltic as we know it today. This was, at the same time, a significant area that saw important transformations in society and economy among the hunter-gatherer communities of the late Pleistocene and Early Holocene. Like Beringia, research here incorporates existing terrestrial sites as well as submerged materials, albeit across a much smaller expanse of landscape.

The earliest records of human settlement here date back some 14,000 years, but the preservation of archaeological material is constrained by the emergence of the area from the mantle of ice. It is, of course, possible that the first communities made use of the ice front and have left little trace. Whenever people first arrived, throughout the earliest millennia of human activity, this area underwent considerable physical change from the initial appearance of an ice-dammed lake about 16,000 years ago, through the incursion of saline waters to form the brackish Yoldia Sea (11,700 years ago), followed by the freshwater Ancylus Lake (10,700 years ago), before the influx of saline waters once again resulted in the development of marine conditions. Throughout this time, changes in relative sea-level meant that a shifting pattern of dryland, islands, watercourses, and open water characterised the landscape. Some of these phases lasted only for a few centuries, and those who lived here, whether permanently, or temporarily, had, over time, to be flexible. Current thinking suggests that this landscape of shifting conditions, emergent islands and blurred drylands/wetlands may have played a fundamental role in helping to shape the developing technologies, evolving economies and societies, and increasing maritime specialisations of northwest Europe in the Early Holocene (Schmitt *et al.* 2006; Bjerck 2009).

One key part of this landscape which has seen intense research comprises the straights between Denmark and Sweden, known today as the *Öresund* (Fischer 2018). The first finds were recovered here in the 1930s and ongoing projects, including accidental finds, targeted research, and investigation in advance of commercial development, have revealed a variety of sites spanning the period from the Younger Dryas onwards (Larsson 2017). While some locations are identified as isolated find spots, excavation has taken place, notably in the early 1990s, at the Pilhaken bank, to the west of the town of Landskrona. The site lies on the banks of a palaeo-rivercourse at a depth of about 8 m below present and finds included flint tools as well as organic material such as animal bone and wood remains which have been able to provide considerable information of the prehistoric environment (Larsson 2017). In general, these finds may be used to enhance the information obtained from archaeology on land in order to provide a more rounded and subtle picture of early human activity in this significant area.

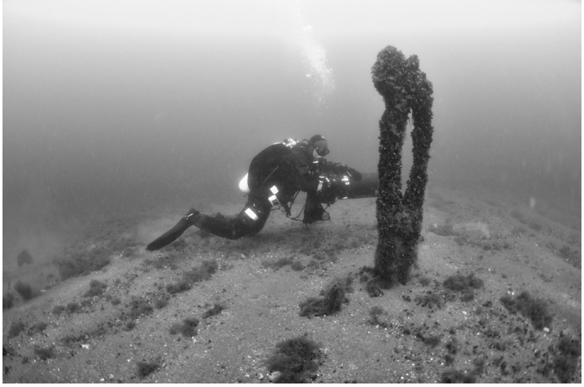


Fig. 11.10 Haväng, Hanö Bay, Sweden, the remains of a pine stump that has been modified for use as a torch. Image: Arne Sjöström, Lund University

To the east of the *Öresund*, on the southeast coast of Sweden, lies the site of Haväng, in Hanö Bay, where an interdisciplinary project, including remote sensing, diver survey, sediment sampling and analysis, across an area of about 2 km2 has resulted in the detailed reconstruction of changing landscapes and conditions from the highest shorelines of the Ancylus Lake throughout the Mesolithic (Hansson *et al.* 2017; 2018). The authors make an interesting correlation, using the preservation conditions of submerged timber remains (Pl. 45) to suggest relative rates of sea-level rise. Well-preserved samples dating to between 11,100–10,400 BP suggest that throughout this period transgression was relatively rapid, thus favouring preservation, whereas the lack of material from more recent periods, suggests that transgression at this point was slower, resulting in more erosion and destruction during inundation. The project recovered some interesting archaeological finds including fish weirs (Pl. 46) and fishing equipment dated to around 9200–8400 BP, as well as worked bone and antler (Pl. 47). During the initial stages of the Littorina Sea, around 9000 BP, they hypothesise the existence of a river running through a series of large bays and lagoons within which people fished for local freshwater and brackish species. While the work was not directed at excavation, the finds do suggest possible locations for settlements in more sheltered areas from which both aquatic and terrestrial environments could be exploited.

The project in Hanö Bay is an excellent example of the rewards of targeted interdisciplinary work and of the wealth of, sometimes surprising, information to be found within the submerged landscape (Fig. 11.10). Future studies aim to extend the project and examine the submerged landscape around the coasts of southern Sweden (Nilsson pers. comm.). In addition to unlocking the archaeological potential and revealing detail of the changing world of the Early Holocene inhabitants of the area, this will provide a powerful management tool to be deployed across a busy commercial marine zone.

Norway

The history of deglaciation across Norway means that, around much of the coastlines, relative sea-levels have been falling, so that submerged landscapes are confined to the southern coasts. In 2011, Nymoen and Skar reviewed the possibilities for the survival of submerged remains along the coasts of Norway and considered the implications of existing sites. Despite possible hints of submerged structural remains in the far north, at Slettnes in Finmark (Nymoen and Skar 2011), their work focussed on the south, where most sites lay. In between, the existence of Mesolithic remains to the east of the island of Dimna is noted but not expanded. Nevertheless, their overview of sites between Kristiansand and Egersund is revealing, not least because of the amount of material that has survived. It is a good example of the way in which sites, when considered in isolation, rarely amount to much, whereas once they are considered in relation to other sites it becomes possible to discern patterns and significance. In all, a total of 11 Mesolithic sites has now been recorded, including burials, isolated finds, assemblages of stone tools, and submerged peats. Nymoen and Skar note that none of the existing sites was found through targeted survey work and they highlight the need for both research on precise sea-level curves along Norway's fractured coasts and for detailed archaeological management and research to include the subsea zone.

Further offshore, to the southwest of the southern Norwegian coast, the evaluation of two areas of the sea floor in advance of commercial windfarms has included a significant archaeological and palaeoenvironmental element (Glørstad *et al.* 2017). Existing data, in water depths of up to 80 m, to the south of the Norwegian Trench, were analysed across a total area of up to 4000 square kilometres. The techniques used drew upon research methods pioneered by Gaffney *et al.* (2007). The results are interesting because they challenge conventional interpretations of the development of the landscape of Doggerland by suggesting that inundation took place much earlier than previously suggested, around 16,450 BP. Glørstad and his colleagues go on to draw on the work of Andersen (2000), suggesting that the Scandinavian and UK ice sheets were conjoined so that the landscape of Doggerland could only exist to the south of this and may have been less extensive than previously supposed. The presence of a large ice mass across the northern North Sea would require the use of new models relating to deglaciation and the configuration of the land. While not yet proven, this is clearly of crucial importance for our understanding of the early peopling of northern Europe and a reminder that we are still working with a young discipline in which further research is vital. This project is discussed in relation to the interpretation of Doggerland below.

12. Submerged landscapes around the world: Doggerland, Britain and Ireland

Doggerland

The landscape of Doggerland, lying between Britain and the Continent, needs no introduction (see pp. 12, 64 and Fig. 1.2). Various research projects, originating from several different countries on either side of the North Sea are working to investigate the landscape, fauna, flora and possible inhabitation of Doggerland as well as the processes and timing of its inundation (see below). First discussed by Clement Reid in 1913 (Reid 1913) and named by Bryony Coles in 1998 (Coles 1998), awareness of Doggerland only really took off in the first decade of the present century with the publication of research by Vince Gaffney and his colleagues (Gaffney *et al.* 2007; 2009). The classic work on Doggerland remains that of this team, undertaken in the early years of the new millennium and responsible for awakening interest in the concept of Doggerland as a physical landscape with a varied topography and changing environment. This was not just a land-bridge across which people traversed as they passed from the Continent to Britain and back again, it supported sizeable communities over time (Fitch *et al.* 2005; 2007). Gaffney and colleagues also demonstrated that it was not always necessary to collect vast amounts of new data for meaningful survey work to give results. Their innovative use of pre-existing, but largely ignored, offshore data sets revealed startling detail of the submerged landscape and the way it had built up and changed over time. It was specialist work, but it yielded excellent results.

Most of the work on Doggerland relates to the southern reaches, though in 2007 Gaffney and his team mapped a sample segment of topography to the northwest of the location of the 'North Sea Flint', a single artefact recovered from a vibrocore off the Viking Bank in 1981 (Long *et al.* 1988; Gaffney *et al.* 2007). Although they comment on the potential for the analysis of landscapes and possible traces of human settlement in the north, no one has yet undertaken wider survey here. Northern Doggerland undoubtedly poses problems of access in terms of deeper water, and more uncertain weather conditions, but it is a key area with regard to understanding the fringes of northwest Europe at the end of the Pleistocene and in to the Early Holocene. While the context (and even antiquity of deposition) of the North Sea Flint remains uncertain (Bicket and Tizzard 2015), the validity of reconstructing the prehistory of an area as large as this on the basis of one flint should also be regarded as doubtful, even were it to be shown to have lain within an archaeological context.

Further south, an example of the way in which understanding of the evolution of the Doggerland landscape is still uncertain is presented by Glørstad and his colleagues in their discussion of the investigation of two areas of seabed to the south of the Norwegian Trench (Glørstad *et al.* 2017). Using three-dimensional seismic data, they were able to reconstruct an intricate pattern of landscape features including river valleys, channels and lakes. A lack of preserved core material limited their ability to obtain dates for these features, but in one instance material had been preserved and it was possible to show that dry land was lacking here in Late Glacial times, rather, the area had transformed directly from lacustrine to marine conditions in the millennia since the end of the last Ice Age. The precise meaning of their research in terms of Doggerland remains tentative. It is hard to extrapolate across a wide area of land from a single core, and it is possible that the sediments reflect localised wetlands. However, they also discuss recent research which suggests that, around the Late Glacial Maximum, a glacial barrier stretching from Britain to Scandinavia may have resulted in an ice-dammed lake across this northern part of Doggerland, considerably diminishing the land available for any groups of Palaeolithic hunters (Andersen 2000). The need for further research, in these key areas, is clear.

There are, nevertheless, accounts of individual artefacts from the central North Sea, as far north as the Fisher Banks, including stone weights, axes, and worked bone (Van de Noort 2011; Verhart 2004). These accompany large quantities of Pleistocene mammal bone which have been recovered further south, in the area of the Brown Bank, by Dutch fishing vessels for many years (van Kolfschoten and Laban 1995) and are now recorded as part of the North Sea Project, an attempt by Dutch archaeologists and their palaeoenvironmental colleagues to investigate the changing conditions of the area from around 44,000 years ago (Glimmerveen *et al.* 2004). Bone finds include mammoth, woolly rhinocerous, brown bear, cave lion, and wolf, and there are also marine mammals such as walrus, harp seals and killer whales, indicating that at times the coastline penetrated south. Although detailed topographical information is lacking, the finds of artefacts indicate that bands of hunter-gatherers shared this landscape with the mammalian fauna, at least from time to time.

Elsewhere in the North Sea, Gaffney and his team are now collaborating with Dutch colleagues to elucidate a wider expanse of landscape detail, from the Dogger Bank area of their earlier research (Gaffney *et al.* 2007), to the Dutch coast (van Heteren *et al.* 2014). A variety of techniques, including seismic survey, has been used to provide three-dimensional reconstructions of submerged and buried land surfaces which not only help to reconstruct the landscape of the late glacial hunter-gatherers, but are also providing important information relating to the conditions, and detailed locations, of glacial ice during periods of re-advance and subsequent shrinking of the glaciers. Sediment samples are now being extracted, using deep sea coring techniques, in order to date the different stages and provide details of the palaeoenvironmental conditions prevailing across the varied landscape elements. Analysis of the various sources of information within a core (pollen, diatoms, ostracods and foraminifera) is a slow business and it can be hard to identify locations where core sediments will be suitable for the preservation of data, but detailed work in the offshore Humber area is providing information (Gearey *et al.* 2017) relating to the dominance of different tree species at various points in time.

Areas of wetland and peat growth can be identified and contrasted with other areas of drier heath. Gearey and his colleagues do much to bring to life their area of study, a submerged palaeochannel, from the late glacial period into the Early Holocene, though the identification of a specific human input into the landscape has yet to occur. Similar work has been announced by a joint team from the Universities of Bradford and Ghent together with the Flanders Marine Institute, in the vicinity of the Brown Bank with the specific aim of elucidating the location sites of artefactual material in order to investigate the possibility that preserved settlement, or other activity, remains survive. Meanwhile, Gaffney and his colleagues are also working to develop new approaches and refine interpretations of the palaeolandscape across Doggerland, using techniques such as the study of aDNA in order to provide information on flora and fauna (Gaffney *et al.* 2017). The combined impact of these projects serves to emphasise the significance of Doggerland as a prehistoric landscape and acts as a testbed for techniques that can then be employed elsewhere.

Given the general acceptance of Doggerland as a significant terrestrial resource for the Late Glacial and Early Holocene hunter-gatherers of northwest Europe it is perhaps surprising that so few publications integrate discussion of the landscape with consideration of the archaeological resource of the time. Peeters and Momber provide a refreshing exception to this in their paper on the human occupation of northwest Europe after the Last Glacial Maximum (Peeters and Momber 2014). Yet even they are forced to rely on three, oft cited, sites: De Stekels on the Brown Bank (Glimmerveen *et al.* 2004); Maasvlakte Europoort at Rotterdam (Verhart 1988); Bouldnor Cliff in the Solent (Momber, *et al.* 2011), and they produce a very generalised overview which, though noting the significance of the coasts and coastal settlement, tends to over-emphasise the impact of rapid sea-level rise on the potential terrestrial fauna and human groups of the area (see Wickham-Jones forthcoming). There is much research to be done on Doggerland, and, at present, investigation is still focussed on elucidation of southern landscapes and palaeoenvironments. Those working on the archaeological record of the time tend to direct their attention to the sites on land in surrounding coastal areas and we have yet to integrate the two properly.

Peeters and Momber also note that, just as with sites on land, the preservation of the underwater archaeological record is subject to bias, both in terms of the types and periods of archaeology represented and in terms of the conditions within which they survive (2014). There are some surprising similarities with terrestrial sites in favourable conditions for preservation, as in the advantages offered by infilled river channels and lakeside locations, while other examples highlight the differences such as the recorded presence of submerged forest remains across areas of the Dogger Bank. Given the variability of the underwater landscape and increasing commercial development in the subsea zone, understanding these biases, and building a predictive map of likely areas of preservation, is vital for successful management of the underwater resource, and the location of possible sites (Ward and Larcombe 2008). Ward and Larcombe's work in 2008 provided the background for this type of study, with an overview of the geomorphological development and current nature of the North Sea bed, though it focusses on the southern North Sea. In addition to describing the different elements that combine to form the seabed, they discuss the processes by which it has been shaped,

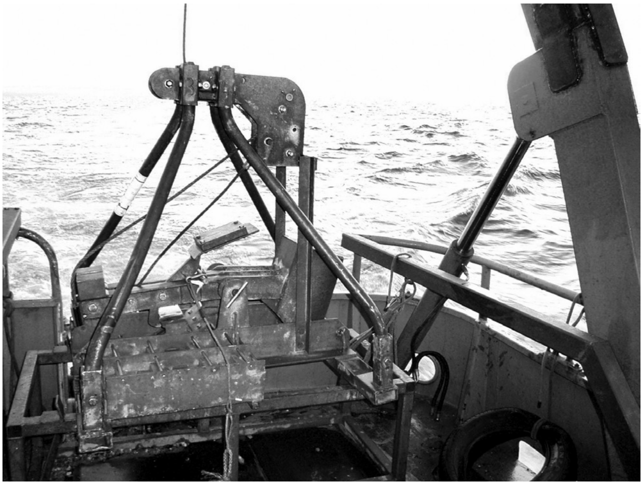


Fig. 12.1 Using a Hamon Grab in order to sample the seabed from an offshore survey vessel. Image: © Wessex Archaeology

including both accumulation of sediment and the impact of inundation on the different landforms as relative sea-levels rose. The study considers current commercial activities and their impact on the different areas of the seabed, and, usefully, they highlight those landform types likely to have high preservation potential for archaeology and their vulnerabilities. This is an important survey, but, despite more recent and lengthier publications (e.g. Flemming *et al.* 2017), there has been little attempt to measure the actual archaeological potential of the North Sea. The majority of research is concerned with landscape reconstruction over specific areas of terrain, rather than possible human remains. This is clearly an important step in understanding the significance of Doggerland at different time slices in British prehistory, but it is important not to lose sight of the goal of actually recovering archaeological data, especially if we are to develop effective management policies (Ward *et al.* 2014). Sturt and Standen (2013) note the management problems of creating empty landscapes with high apparent archaeological significance underwater, and they contrast them to the preponderance of intensively 'populated' archaeological zones on land.

In some cases, however, finds do occur and can be studied. In British waters, the development of a protocol for the reporting of archaeological finds recovered during the dredging or processing of aggregates from marine environments (Wessex 2005) has led to the recording of some notable material. In particular, it is known for a large assemblage of Palaeolithic stone tools and faunal remains from a dredging area known as Area 240, some 11 km off the coast of East Anglia (Tizzard *et al.* 2014). Once the material had been registered and processed it was possible to return to the area and conduct targeted archaeological research, including multibeam and seismic surveys, the extraction of sediment samples with vibrocores, and archaeological sampling with seabed grabs (Fig. 12.1 and Pl. 48). In this way, it was possible to reconstruct the landscape and conditions of deposition (Pl. 49), as well as undertake analysis of the artefacts themselves (Tizzard *et al.* 2015). The end result provides a significant contribution to understanding of the human occupation of Britain in the Early Middle Palaeolithic. Although the site lies under water depths of between 20 m and 35 m today, the research has focussed on understanding the deposition in the widest terms as within a palaeoriver system, the Palaeo-Yare, running east and north, across the low-lying plains of the early Doggerland landscape. The timing is crucial, suggesting as it does, that Neanderthal activity in the UK extended across both cooler and warmer conditions some 60,000–200,000 years ago.

Although there has traditionally been little evidence for the human settlement of Britain at this time (Pettit and White 2012), this research opens the way for a wider interpretation of Neanderthal colonization, survival, and the development of different cultural groups in the area. Excitingly, the first fragments of Neanderthal skull have also recently been recovered from North Sea assemblages, though the definitive results of analysis have yet to be published (Rincon 2009). Bicket and Tizzard have progressed this study of the palaeogeography and known human activity of the southern reaches of Doggerland in the Middle Palaeolithic in an interesting overview which reminds us that Doggerland is not just about the Early Holocene (Bicket and Tizzard 2015).

The UK and Ireland: General surveys

Several broadscale surveys and audits around the shores of the UK and Ireland have sought to characterise the submerged landscape and categorise potential for the preservation of archaeological remains. In 2013 Wessex Archaeology published an audit of England's inland and offshore waters, with the aim of summarising existing work and raising awareness relating to submerged palaeolandscapes and sites (Wessex 2013). An ongoing problem with the investigation of submerged landscapes is that research can be published in a wide variety of contrasting ways including specialist or commercial websites, academic and local society journals, and popular books (or not published at all), and it is not always easy to access. It can, indeed, be difficult to find out what work has taken place. It is also the case that the standards, approaches, and resolution of research undertaken by different bodies varies greatly. The results of Wessex Archaeology's investigations provide a comprehensive overview of the state of submerged landscape research and understanding around the coasts of England in the early 21st century, with some basic analysis of the results and a useful inventory of projects and sources.

A similar data audit was published for Scotland in 2011 (Wessex 2011), with the aim of creating a database of sources and organisations. This was not intended to be an overview of knowledge to date; it was designed as a much more rapid piece of work to provide a summary of appropriate techniques and existing data sets. It does, however, include discussion of the strengths and weaknesses of existing approaches, together with recommendations of relevance for future research and management. Interestingly, this document takes a very different approach to other audits and surveys as the results are not organised geographically, but rather by technique. It perhaps reflects the relative lack of recent work in Scotland compared to other parts of the UK.

On the west coast of England, in 2011, publication of the West Coast Palaeolandscapes Project recorded the investigation of the outer Bristol Channel and the southeast Irish Sea, in order to assess the potential for the preservation of submerged landscapes using existing seismic and bathymetric data (Fitch and Gaffney 2011). Previous work on relative sea-level change in the area was combined with a range of information in order to identify relevant landscape features and deposits and produce an outcome that might be of value to both archaeological interpretation and management. The project was able to record a considerable number of relevant features in both target areas, including glacial lakes, peat deposits, and Holocene channels. From this it was possible to build maps of archaeological and landscape potential for the offshore area and the discussion considers the changing landscapes and palaeoenvironments of the two areas, through the Late Glacial and Early Holocene. This work is of considerable value for both archaeological understanding and management. While detailed data analysis would be necessary to relate it to the activity of specific human communities, the study provides an excellent example of the possibilities of work undertaken using pre-existing data. It makes a useful management tool that should be used to flag up potentially fragile or significant deposits in advance of commercial development.

The seabed around Ireland has been surveyed in detail and, while the data is easily available (INFOMAR n. d.), the focus of research on the submerged landscape lies along the north coast (Quinn *et al.* 2008). Westley and Edwards provide a useful summary of the changing landscapes of the continental shelf around Ireland, in which they combine existing models of deglaciation and changes in relative sea-level, together with discussion of existing marine data sources, likely locations of palaeoenvironmental and archaeological preservation, and suggestions for future work (Westley and Edwards 2017). While this is, of necessity, a broadscale survey, a more detailed case study relating to the north coast is published by Westley and colleagues (Westley *et al.* 2011b). In general, all of the research combines modelled information relating to relative sea-level change with bathymetric and other survey data, where it is available, in order to provide palaeogeographic reconstructions of the coastal landscape at different time slices in the past. Where more detailed survey is possible, these have been combined with information relating to known archaeological sites, in particular flint scatters, so that likely locations of high archaeological value can be predicted (Pl. 50). These locations include the mouths of sealochs such as Lough Swilly and Lough Foyle. Westley and his colleagues note that while the existing bathymetric data are not sufficient to locate early prehistoric sites, it can be combined with other data sources into a predictive tool that is of use for both seabed management and archaeological survey (2011b). In order to test the predictive nature of the work, short dive transects were then completed with the aim of examining both the palaeoenvironmental context and the possible recovery of stone tools. One particular location, Eleven Ballyboes on the western shore of Lough Foyle, yielded worked flint from both the intertidal zone and underwater, and test pitting suggests that the actual site lies offshore in around two metres of water (Westley 2013). In this case, Westley notes that it took the divers a while to recognise the individual stone tools among a gravelly substrate, but the results are clearly worthwhile. Initial calculations suggest that the flints are likely to date from the Early Mesolithic, some 9000 years ago, though more work is ongoing to date the site more precisely.

The Irish studies demonstrate the value of working from broadscale overviews towards localised surveys.

The UK and Ireland: Specific sites and localised surveys

One of the best-known examples of a submerged landscape and archaeological site in the UK must be the Mesolithic site at Bouldnor Cliff (Pls 19–21), in the Solent, dated to 8000 BP (Momber *et al.* 2011). Timely publication of the initial results (including innovative three-dimensional models), together with ongoing work (Pl. 51), has ensured that this site, which lies at a depth of around 11 m just off the west coast of the Isle of Wight, is frequently cited as an example of the benefits and rewards of detailed project work underwater (including excavation and a suite of techniques of sediment analysis). There are, indeed, to date, no other examples of the excavation and investigation of archaeological material within a landscape context from this period in the UK. Although individual field seasons are short, and it has only been possible to excavate fragments of the apparently extensive site here, Bouldnor Cliff continues to push the boundaries of understanding, yielding information related to Mesolithic boat-building techniques and woodworking in general, and of the occurrence of possible cereal type grains (identified by aDNA) well before they are generally recognised to have reached the UK (Smith *et al.* 2015). Headline-grabbing research such as this aside, Bouldnor Cliff is a significant discovery and it is a shame that comparable finds elsewhere have not yet been made. Whether this reflects the problems of locating sites, the lack of preservation of archaeological material, or the deflection of resources and enthusiasm to known find spots, remains to be shown.

Further to the west, the shallow waters and sinking shorelines of the Isles of Scilly present likely conditions for the existence of submerged archaeology and landscape information. Research by the Lyonesse Project has focussed on the reconstruction of the evolution of the archipelago through the post-glacial rise in relative sea-levels using a mix of survey techniques, sediment sampling and dating (Johns *et al.* 2009). From a single island around 9000 years ago, the archipelago of today has gradually evolved, though palaeoenvironmental research indicates that extensive tracts of intertidal salt marsh were still extant around 3500 BP (Charman *et al.* 2016). This landscape change coincides with the history of human settlement in the islands, evidenced by recently excavated Mesolithic and Neolithic material on land (Anderson-Whymark H *et al.* 2015; Garrow and Sturt 2017). Archaeological work in the submerged zone has focussed on the recording of upstanding remains between the islands, such as field walls (Pl. 3), but it is clear that the island community of the past had to be flexible in the face of considerable geographical change. Given that the record of this human adaption may well lie preserved in the shallow sediments of the archipelago, further research here is likely to be well rewarded.

The deeper waters of the Bristol Channel provide a stark contrast to the shallow inter-island seas of Scilly, yet the potential for research related to submerged landscapes and past human activity has not been ignored in both offshore and intertidal zones. While much of the seabed within the Bristol Channel comprises scoured bedrock, in some areas pockets of sediments do survive and these include peat deposits. Sturt and colleagues used a combination of seismic survey with vibrocores, in work across a segment of the channel offshore from Hinckley Point (Fig. 12.2) (Sturt *et al.* 2013). The core sediments were assessed for a variety of data including pollen, foraminifera, diatoms, and molluscs and radiocarbon dating was undertaken to build a picture of the changing environment through time in the Late Glacial and Early Holocene. This research provided a clear picture of the changes to the Early Holocene vegetation caused by a rise in relative sea-level from 9500 BP. Interestingly, considerable evidence of local burning was recorded in the plant macrofossils relating to shoreline reed swamps and dated to around 7100 BP. This type of burning has been noted elsewhere and it is often

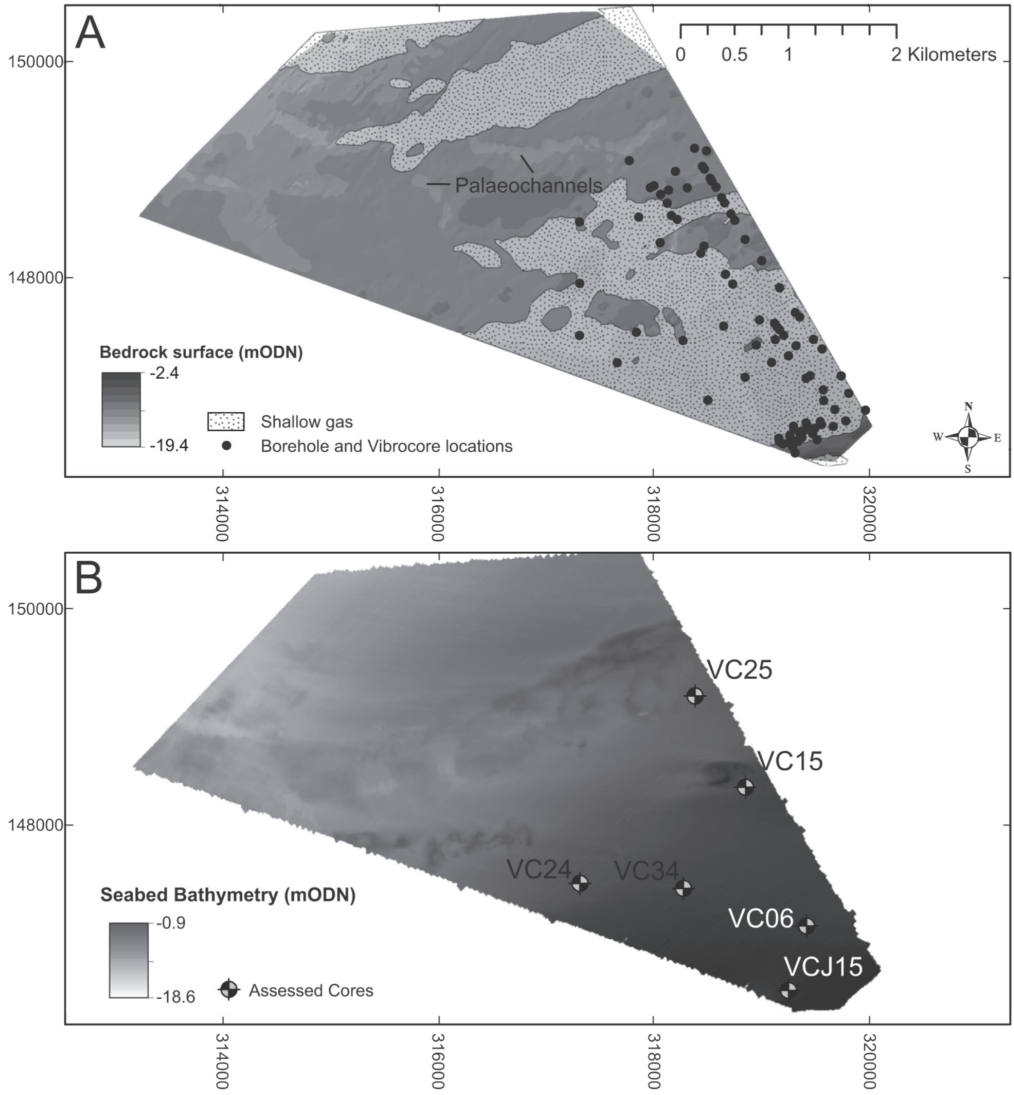

A
0
0.5
1
2 Kilometers
150000
148000
Palaeochannels
Bedrock surface (mODN)
-2.4
-19.4
Shallow gas
Borehole and Vibrocore locations
N
W
E
S
314000
316000
318000
320000
B
150000
148000
VC25
VC15
VC24
VC34
VC06
VCJ15
Seabed Bathymetry (mODN)
-0.9
-18.6
Assessed Cores
314000
316000
318000
320000

Fig. 12.2 Investigation of the submerged landscape in the Bristol Channel, showing palaeochannels and the location of boreholes. Image: Fraser Sturt, University of Southampton. From Sturt et al. (2013)

related to human activity which may well be the case here. As relative sea-levels rose, peat deposits gave way to brackish and then marine conditions; the resolution of the sampling was such that it was possible for the authors to illustrate the way in which marine flooding did not take place as a smooth uniform event, but rather in a series of stops and starts. This sort of detail is a useful reminder for those who rely on more broadscale modelling, of the value of localised and high-resolution data.

Although there was no direct evidence for human activity in the offshore deposits examined by Sturt and colleagues, worked flint has been found in the intertidal zone not far to the west (Canti et al. 1995), and extensive and varied remains, including stone tools and spreads of footprints (Fig. 12.3) have been investigated by Bell and his team at Goldcliff on the northern shores of the Bristol Channel (Bell 2007). Bell's interdisciplinary project has combined a variety of techniques, including archaeological excavation, as well as sediment sampling, and survey work, to detail the history of landscape change in the Early Holocene along this stretch of coastline, and the changing lives of the human communities who lived within it.

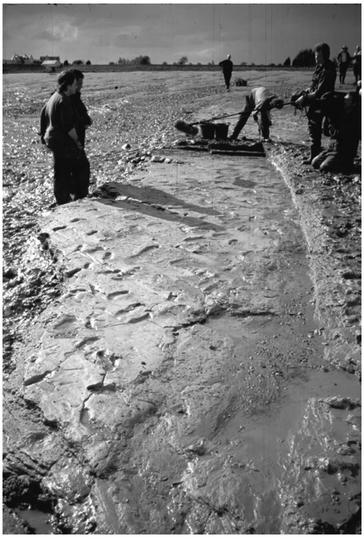


Fig. 12.3 Goldcliff, human footprints under excavation. The fragile nature of the deposits in the intertidal zone is clear. Image: E. Sacre, Goldcliff Project

The remains at Goldcliff include traces of a submerged forest (Fig. 12.4), an evocative reminder of the power of any rise in relative sea-levels. Ancient, submerged forests have been recorded in the intertidal zone in several locations around Wales. One of the most cited locations lies at Borth, in Cardigan Bay, where there is a long history of research (Godwin and Newton 1938; Groom 2011). The deposits at Borth include beds of peat (Pl. 52) as well as numerous well-preserved tree stumps (Fig. 12.5) and other forest matter such as twigs and small branches; they are remarkable for the traces of human activity across a relatively long time span, with which they are associated. The earliest indication of a human presence at Borth comprises a Mesolithic adze of flint, set within an antler sleeve, while a hearth and a series of human (Fig. 12.6) and animal footprints are thought to date to around 4000 BP. There are also scatters of stone tools and in 2014, a wattle walkway, dated to the 4th millennium BP, was exposed during winter storms (Coflein 2012). The variety of material at Borth is a reminder of the potential of sites like this, even when they lie in locations such as an actively eroding and popular beach that might not be considered of great archaeological value.

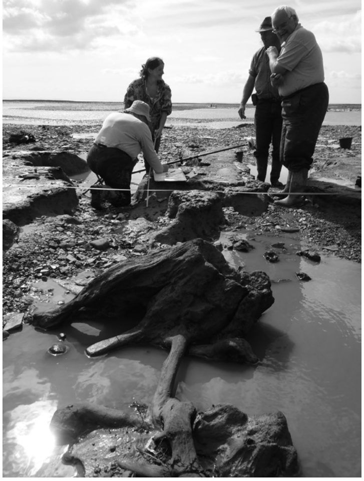


Fig. 12.4 The intertidal remains at Goldcliff, include substantial tree remains, some of which have been dated to around 7800 BP. Image: Martin Bell, Goldcliff Project

Human footprints provide an intensely personal reminder of the peoples of the past. Preserved in the soft muds of a salt marsh, or at the water's edge, they reflect only the briefest moments in time. Nevertheless, their detailed study, as at Goldcliff (Bell 2007), can

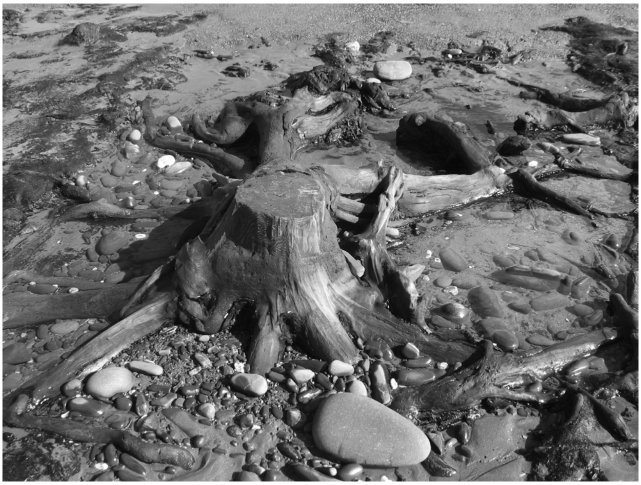


Fig. 12.5 One of the impressive stumps from the intertidal forest at Borth, Wales. Image: Martin Bates, University of Wales, Trinity St David

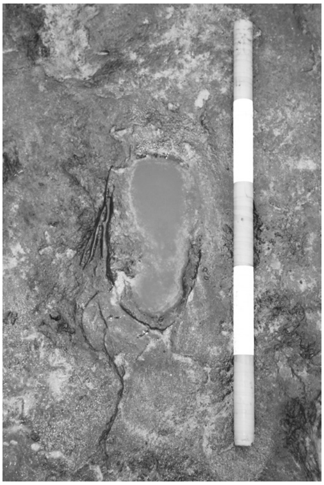
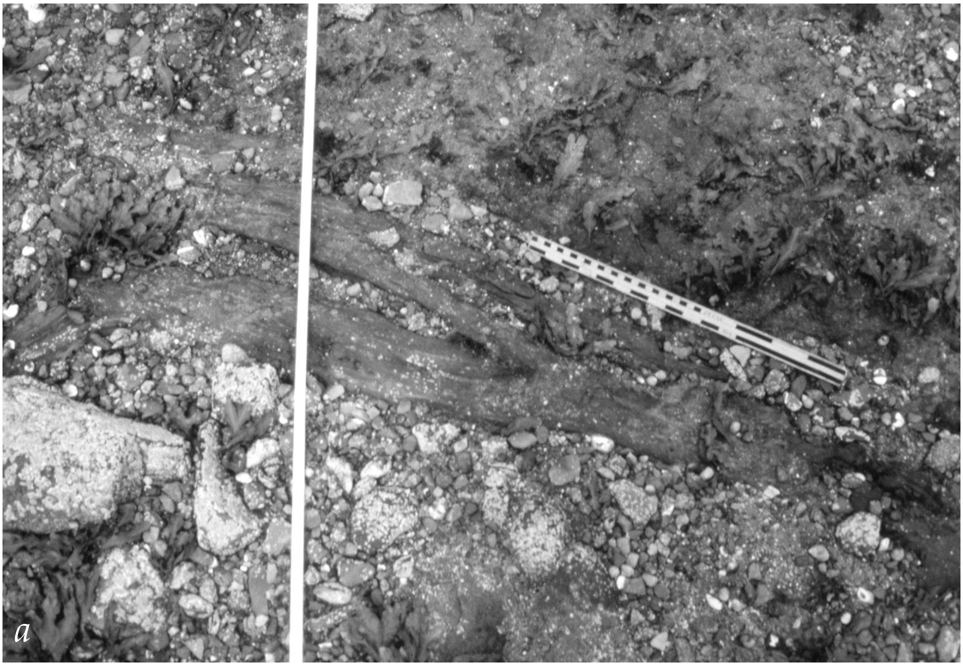


Fig. 12.6 The footprint of a child preserved in the intertidal peat beds at Borth, Wales. Image: Martin Bates, University of Wales, Trinity St David

reveal surprising detail of individuals including both personal characteristics and the activities they were undertaking. Perhaps surprisingly, footprints have been recognised at increasing numbers of sites around the UK. In 2014, footprints from a group of children and adults dating back some 7000 years were discovered at Port Eynon on the Gower Peninsula (Philp 2017).

The study of submerged landscapes and intertidal sites in Scotland is relatively recent, perhaps because of the dominance of ideas of gradually lowering relative sea-levels and emerging coastlines, as evidenced by the photographs of raised beaches which occur within many basic school text books. Nevertheless, at least two intertidal sites, both comprising lithic scatters from early prehistory, have been recorded. At Clachan Harbour on the island of Raasay, stone tools have been recovered from an intertidal peat deposit (Cressey *et al.* 2007). Though there is no detailed published date for this site, the palaeoenvironmental evidence (Fig. 12.7) suggests that the deposits pre-date a marine transgression that took place around 9500 BP. Some 40 km to the northeast at Lub Dubh Aird, worked stone has been collected from the intertidal zone and further material recovered by test pitting, though survey offshore did not reveal archaeological finds (Hardy *et al.* 2015). In all, the assemblage from Lub Dubh Aird numbers over 2000 pieces, and it has been dated, from its palaeogeographic position, to the Early Mesolithic. Further west, a wider archaeological survey around the coasts of the Sound of Harris sought to prospect for submerged archaeological sites and palaeoenvironmental deposits (Bicket *et al.* 2017b). Although hampered by a lack of precise data on relative sea-level change which limited the team's ability to identify the palaeolandscape setting for specific time periods, this project was able to highlight the considerable change that had taken place here throughout the Early Holocene. By



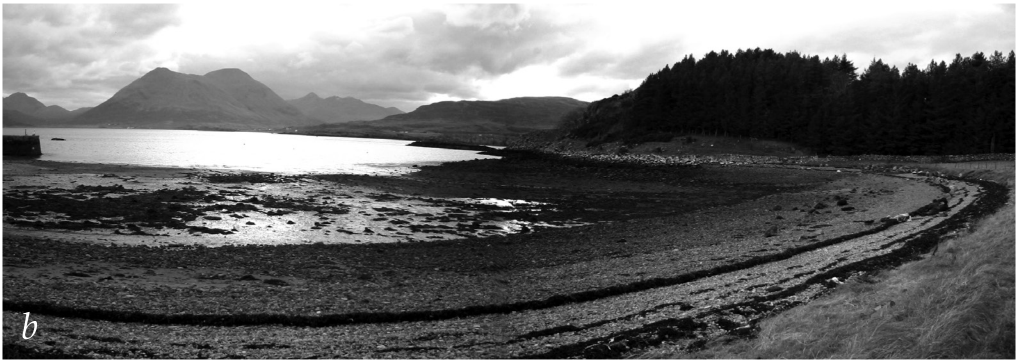


Fig. 12.7 Clachan Harbour, Raasay, Scotland: a) detail of preserved timbers; b) intertidal peats in the bay. Image: Scotland's First Settlers

linking to sites on land, the archaeological potential of specific locations within the coastal and offshore landscape could be emphasised.

A rare example of the investigation of submerged early prehistoric material in inland waters is provided by the Submerged Neolithic of the Western Isles project, based at the Universities of Southampton and Reading under the leadership of Fraser Sturt and Duncan Garrow (Sturt n. d.). Using a mix of conventional archaeological excavation, diving, remote survey, and sediment analysis, the team are investigating island sites within the shallow lochans of the islands, all of which provide evidence for Neolithic

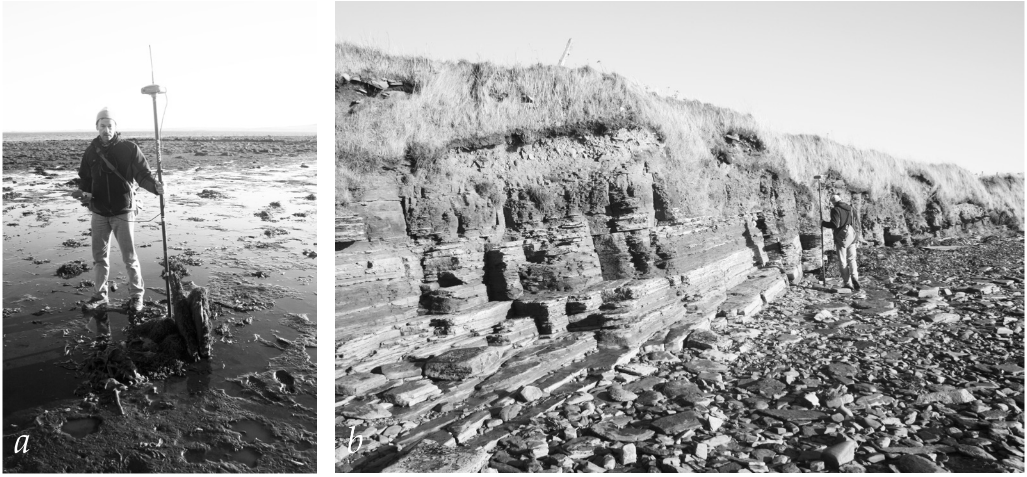


Fig. 12.8 Orkney, Scotland, survey work on stone features to be found in the intertidal zone: a) anthropogenic; b) natural. Images: Martin Bates, University of Wales, Trinity St David

occupation (Pl. 53). At least three of the islands are artificial, created in the Neolithic, and the finds include particularly well-preserved pottery (Pl. 54) (Sheridan *et al.* 2014). Islands, such as these are known as crannogs, and they are well-researched around Scotland and elsewhere (Dixon 2004), but they usually date to the Bronze Age and later. The team have had to adapt their usual deep-water equipment and techniques in order to access these remote and shallow locations, but the results are providing valuable information relating to the palaeoenvironment and way of life in what might, once, have been considered, a marginal environment (Sturt n. d.).

Research along the north coast of Scotland has focussed on relative sea-level change and the elucidation of deposits from the Storegga tsunami (Dawson and Smith 2000). In the waters of Orkney, the Rising Tide project, while maintaining an avowedly archaeological outlook (and, mainly, funded by archaeological bodies), has found the identification of anthropogenic material underwater to be problematic. This was initially surprising, given that relative sea-level rise in Orkney continued into the 4th millennium BP meaning that sites dating from the Early Neolithic, and therefore likely to be stone built, might be encountered (Bates *et al.* 2013a). However, consideration of the likely taphonomy of dry-stone buildings preserved underwater for some four millennia in an area where building stone resembles naturally occurring bedrock, suggested that the team might have been over-optimistic in their assumption that it would be easy to distinguish between a collapsed building and a dump or outcrop of rock (Fig. 12.8). Despite the lack of sites, the work of the Rising Tide project has continued with the aim of providing a more accurate landscape context for the rich Neolithic archaeology of the islands (Wickham-Jones *et al.* 2016). This is an interdisciplinary project that combines extensive sonar and seismic survey with sediment analysis (Fig. 12.9) to build a picture of the changing landscape of Orkney as relative sea-levels rose throughout the Early Holocene, and to relate this to both Mesolithic and Neolithic archaeology (Bates *et al.* 2016). Of course, the goal of locating submerged archaeological sites has not been set aside, even

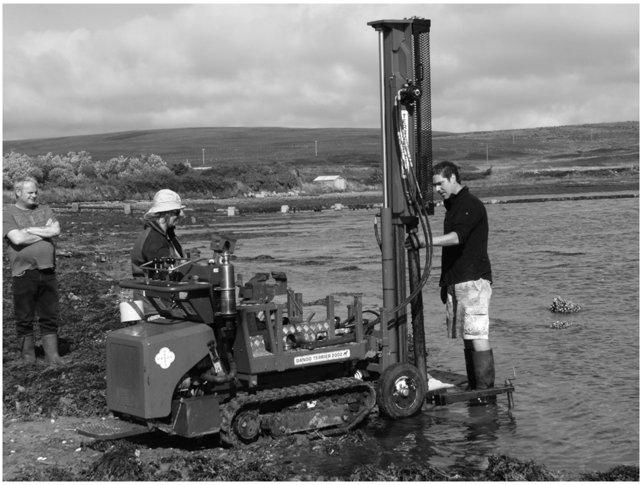


Fig. 12.9 Orkney, Scotland, taking a core in the intertidal zone

if the team is more realistic about achieving this.

To the north of Orkney lies the island chain of Shetland. In 1990 marine dredging in Bressay Sound, in conjunction with the maintenance of the harbour, recovered a considerable quantity of timber, identified as birch, together with a polished stone axe of Neolithic date. This is interesting because general models indicate that relative sea-levels around Shetland were considerably lower in the Neolithic, rising from around –25 m OD to around –12 m OD in the period between 8000 BP and 6000 BP. Detailed investigation of the submerged landscape around Shetland is lacking, as is research to obtain accurate sea-level indicator points, but resolution of the evolution of these northern landscapes is critical to understanding of the early population of the British Isles as a whole.

The work in Orkney has also been used to investigate the impact of different scales of analysis at which research takes place, from the broadscale models that cover the entire North Sea to the detailed models that encompass a single bay. From this it is possible to suggest the appropriate levels of research necessary in order to investigate the impact of inundation and landscape change on individual human communities (Wickham-Jones *et al.* 2018). Relating submerged landscape research to the prehistoric inhabitants of an area is also impacted by a phenomenon identified by some as White Ribbon Archaeology: the problems of obtaining data, in particular survey data, from the shallow waters that run along the coast. Many scientific survey vessels require too deep a draft to operate in the immediate coastal zone. The problems of the 'White Ribbon' can mean that it is hard to demonstrate a direct relationship between sites on land and the submerged landscapes just offshore.

The impact of White Ribbon Archaeology has been tackled by Wessex Archaeology in a case study along the Northumbrian coast in which they sought to provide a more complete landscape context for two Early Holocene sites on the coast (Howick, Waddington 2007; Low Hauxley, Waddington 2014). In order to achieve this, they set out to acquire and analyse new data from this zone (Bicket *et al.* 2017a). While the research lacks a precise sea-level curve for the area, and highlights the shortfalls of a lack of collaboration between archaeology and other geosciences, the results are interesting and provide pointers for future investigation. Due to the lack of Sea-level Indicator Points, a possible error margin of up to 15 m is identified in estimates of relative sea-level around 10,000 BP, at precisely the time when the early communities of the area were active. Seabed sediments in the survey area were rare and relate to the last glaciation, rather than the Holocene, limiting the possibilities of obtaining data relevant to relative sea-level in the Early Holocene from the nearshore marine zone. Nevertheless, two possible palaeo-shorelines were identified at –10 m and –20 m, and potential intertidal zones could be calculated for each. This provided an indication of likely areas of human interest with regard to resource extraction in the past, though it has not yet been possible to date either shore. Although precise interpretation is therefore limited, the research does indicate the likely distances of the two sites to the coast and the probable evolution of the coastal landscape during occupation, including the locations of nearshore palaeo-islands. While this is speculative, it does set up hypotheses that could be tested, for example using land-based sediments and the sampling of submerged peat deposits, in order to start to constrain the picture. It is also possible to use the reconstructed models of the landscape of the Early Holocene here to predict the locations of other archaeological sites and this has obvious useful management implications. Research such as this is an important reminder of the significance of the submerged landscape around the coastal zone and the way in which it cannot be ignored in discussions of the early settlement of the British Isles. As the authors note, this particular stretch of the Northumbrian coast is a key location relevant to discussions of the penetration of settlement into Britain from Doggerland in the Early Holocene.

A more detailed study, integrating the archaeology with a variety of palaeoenvironmental research, has been undertaken in Hartlepool Bay, where the remains of a submerged forest were first recognised in the late 18th century (Waughman 2005). The reconstruction of changes in relative sea-level here includes dates drawn from various sediments going back some 10,000 years. The vegetation history covers the period between 7000 BP and 3000 BP, to produce a detailed depiction of the changing landscape, and archaeological remains go back to the Mesolithic. The specific sites from the bay are then integrated into a wider study of the surrounding region. It is a good example of the potential of coastal areas such as this and of the way in which shifting patterns of archaeology and landscape are intertwined through the ages.

Further south, along the coast of Norfolk, the discovery of human footprints preserved in coastal deposits dated to the late Early Pleistocene has led to research on a much earlier submerged landscape dating to between 1 million and 750,000 years ago. The alluvial and estuarine deposits of Happisburgh have long been recognised as the source of archaeological and palaeoenvironmental material relating to this period, including stone tools, and the investigation included general monitoring together with boreholes dug to obtain sediment samples (Ashton *et al.* 2014). In 2013, however, a larger horizontal exposure was created at the site due to cliff erosion, and this revealed a series of depressions identified as footprints (Fig. 12.10). Given the likely date of the remains, and the fragility of the deposits as they were attacked by the tidal waters, rapid recording of the archaeology included laser scanning, photogrammetry and modelling. Investigation of the early landscape at Happisburgh focusses on both local, coastal deposits (Westaway 2011), and offshore sediments (Wessex 2008) in order to shed light on a landscape that is not only submerged but also, potentially, buried under other, more recent, deposits. Happisburgh is a powerful evocation of the way in which the submerged landscapes that surround Britain relate to various iterations of the geography of this corner of northwest Europe, not just the most recent.

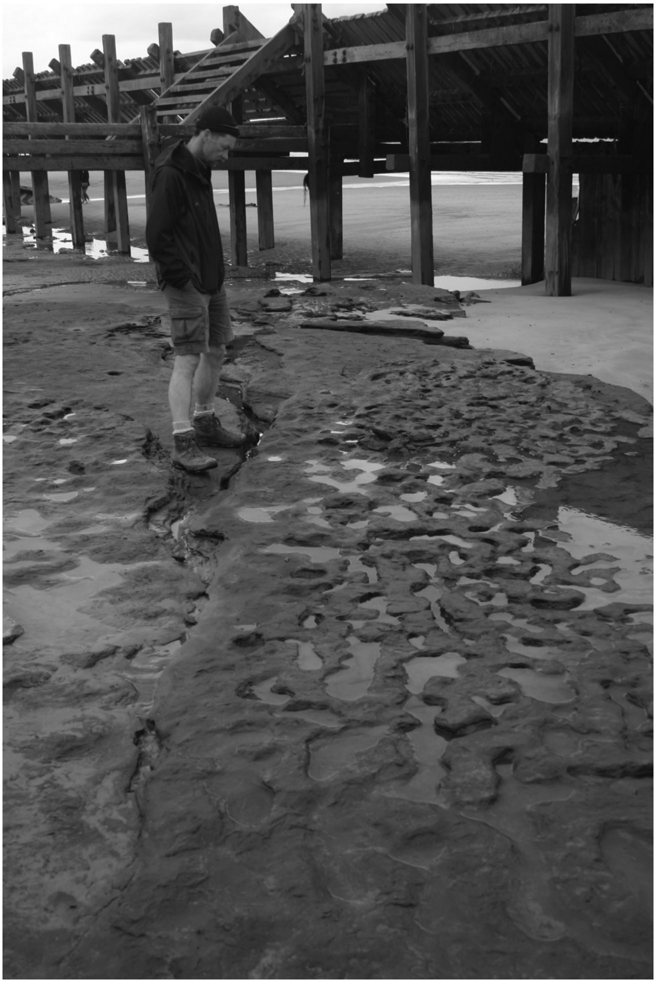


Fig. 12.10 Happisburgh, Norfolk, the Palaeolithic footprints; the vulnerable position of the deposits, being eroded by the sea, is clear. Image: Martin Bates, University of Wales, Trinity St David

Elsewhere, ongoing projects on the submerged landscapes of the UK include work on other, more recent, sites where footprints have been recorded in the intertidal zone, such as at Sefton and Formby (Roberts 2014). There are also an increasing number of locations where submerged and intertidal forests have been exposed and are subject to research, such as at the Pett Levels in Sussex and Bay of Ireland in Orkney (both, Scott Timpany pers. comm.). As an island surrounded by waters with a dynamic history of relative sea-level change, study of the submerged palaeolandscape is an important field for Britain and one which can only develop. Recent advances in technology make it possible to elucidate intimate detail of the topography, aDNA can be used to investigate the flora and fauna, and we can model the results in order to shed light on the likely human use of the landscape. Consideration of the earlier landscapes within which Britain sits is an evocative reminder of the way in which the political boundaries of today are meaningless with regard to the physical geography of the past so that multinational as well as interdisciplinary work is necessary in order to understand the world of our ancestors. This is one of the fun things about archaeology.

13. Conclusions

Reading through the preceding chapters and thinking about the techniques of studying submerged landscapes and existing work around the world, it is easy to lose sight of the people behind the technical archaeology. But the fact is that archaeology deals with people. By itself, a book like this is, necessarily, mechanistic, but as archaeologists we need to take it further than that. The studies we undertake, and the projects we organise, are merely a means to an end: shedding light on ancient lives, on the communities of the past. Fascinating though the processes and projects are, in essence, this is a book about loss, human loss and the emotions and reactions triggered by that loss. I would like to conclude with an attempt to return to the communities around which I base my archaeology.

All of those whose remains have been uncovered by the projects detailed in the preceding pages have had to come to terms with great change in their lives. Whether they knew the loss of their homes at first hand (which, I suspect, relates to the minority of the communities), or whether they had to adapt to a landscape that was undergoing continual transformation, it is likely that, for most communities, the experience would still be stressful. Archaeologists tend to measure time in centuries; one, two, or even 300 years is often considered a short time by those who discuss dating. But, our own experience tells us that much can happen in that time span. Yet, by and large, those of us who live in western Europe, or the body of mainland North America, today, have lived through very stable conditions over the last couple of centuries. We have rarely had to face landscape change or rising sea-levels on the scale that our ancestors experienced them. We have, perhaps, become complacent. We have certainly become reliant on the world as we know it – our technology and our way of life rely on the use of set amounts of land for very specific purposes: food production, housing, transport. Because of this we tend to find the idea that relative sea-levels might rise in the centuries to come very challenging. This is no idle threat; population sizes are much greater, technology has been developed for highly specific conditions, and, as a society generally, we are far less flexible than our ancestors. We have come to rely on the benefits of well-drained land for our cities, roads, and farms. Those who lived in the past had to adapt. They did not have the luxury of becoming habituated to stability as we have, and, in some ways, they were better equipped to survive. But how did they feel about it?

Of course, we have (as yet) no way to elucidate the precise feelings and emotions experienced by those in the Early Holocene who had to make the decision to shift a village, give up farmlands, or abandon sacred territories that were significant to their grandparents. But we do have more recent accounts of communities who experienced this type of event. These, very differing, situations provide an idea of what it can be like to live through both long-term and sudden landscape change. Studying situations like these can help us to enrich our interpretations of those communities in the past who also lived in fragile locations or coped with landscape change.

Dunwich

The village of Dunwich lies on the east coast of England, in the county of Suffolk. It is likely to have Roman origins, and thrived due to the fishing industry. By 1086 it had become one of the ten largest towns in England. It was a market town, as well as a significant religious centre, and it became an important port with widespread connections (Comfort 1994). At its height, the population of Dunwich is estimated to have been as much as five thousand, and yet Dunwich today is a small village, with a population of just over one hundred; three main streets survive, atop the East Anglian cliffs (Fig. 13.1). The demise of Dunwich has been recorded over the centuries from as early as the Domesday Book (record available at the National Archives: http://www.dunwich.org.uk/), through a combination of storms and coastal erosion which have claimed both farmland and houses. Particularly significant periods of loss took place between AD 1275 and 1350, in the second half of the 16th century and in the 18th century, though the Church of All Saints only finally disappeared over the cliff in 1919, and the surviving lands are still vulnerable today. Between 2007 and 2012, the Touching the Tide Project has sought to investigate the site for information relating to the processes and pace of loss, as well as possible surviving archaeological remains (Sear 2015). Using a combination of marine archaeology techniques, documentary searches including old maps, and conventional terrestrial excavation, it has been possible to recreate images of the town at key time-slices in the past as well as to identify the surviving underwater remains of specific buildings such as churches and chapels (Sear *et al.* 2012). Despite the seemingly impossible task of recording an archaeological site that had been lost to coastal erosion, the team has shown that, in the right circumstances, remains can survive and today Dunwich provides an excellent example of a submerged historical landscape.

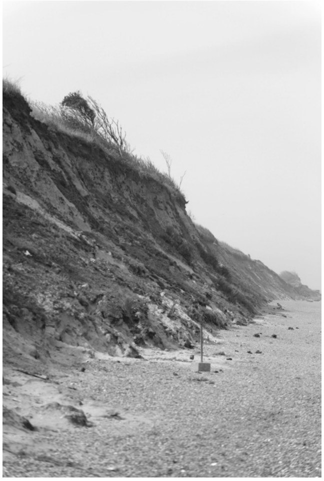


Fig. 13.1 The unstable coastline of Dunwich, in Suffolk, betrays the vulnerability of settlements near to the sea. Image: Paul Hebditch, Alamy Stock Photo

Down the centuries, therefore, the people of Dunwich have had to adapt to their changing circumstances. The historical accounts relate how they worked hard to protect the harbour on which they relied. They tend to focus on the physical loss of land and institutions, but it is not difficult to read between the lines. In AD 1222 the townsfolk obtained a grant from the Crown to rebuild a sea wall which had been lost due to flooding (Scarfe 1970), while Gardner (1754) reports on the fluctuating fortunes of the fishing industry at Dunwich and of the town in general as the harbour silted and had to be repaired and then moved. It is a moving story of constant endeavour and loss.

While the records for Dunwich focus on material loss during centuries of storm, flood and coastal change, it is possible to put it into perspective using accounts of a more recent storm, the so-called 'Great Storm of 1953', which also affected those living in the same area. Archived photographs and oral accounts present a vivid picture of the devastating impact of individual catastrophes from events such as this which result in loss of life, the destruction of homes, fields and infrastructure (Baxter 2005). It takes a community a long while to recover, some would say the inhabitants never do. Since 1953, and partly as a result of that event, there have been considerable developments in the prediction and mitigation of coastal storms around the UK (Hunt 2005; Met Office 2013).

Lake Attabad

Lake Attabad lies at a height of some 2200 m in the Himalayas, in northern Pakistan. It is 11 km long and over 100 m deep. Prior to 2010, this was dry land, part of the Hunza Valley (Fig. 13.2), a fertile area, populated by small settlements as the Hunza River wound down from the border with China at the Kunjerab Pass. It is, nevertheless, an unstable region, emphasised by earthquakes in 2002 and 2005. In January 2010 a landslide occurred, blocking the Hunza River and triggering flows of mud and debris both upstream and downstream. The blockage measured some 400 × 2000 m horizontally and was at least 200 m deep, effectively preventing the flow of the river for so long that initially the lake rose by 4 m a day. By May, the lake was fully formed, and water started to escape down a newly constructed spillway. It had flooded five villages, two of which were completely submerged. Over 6000 people were displaced, and up to 25,000 inhabitants of the valley had been affected. In addition to their homes, people lost farmlands and, initially, links downstream to the main part of Pakistan were cut. While the necessary rehousing did take place, communities were split and people still had to look out over the body of water that concealed the places they had known and loved. The Karakoram Highway, which runs along the valley, is a major economic and tourist routeway, and has since been realigned. Initially, goods and people were carried

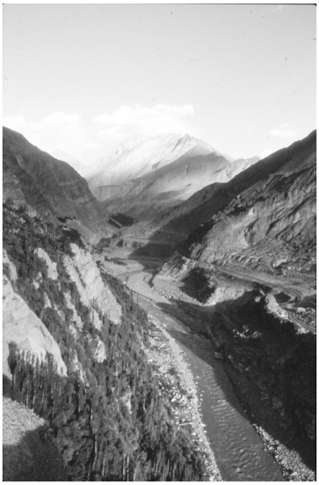


Fig. 13.2 The Hunza valley prior to the formation of Lake Attabad. Vulnerable areas are not always those we might expect

across the lake on small boats and a lively business sprang up among local ferrymen, but this has ceased with the construction of a tunnel and the realignment of the road.

There are some interesting accounts of the social impact of the event. Iqbal and colleagues (2014) relate that, in the days preceding the landslide, local people were alarmed by wide cracks developing in the ground surface and by the noises emanating from within. With the help of local agencies some villages evacuated, thus saving many lives. While the death toll was kept down, the impact on the communities has been long lasting. Those in the path of the disaster had to cope with evacuation, new homes and the problem of finding new work in an area that had undergone such a catastrophic change, many more families were split apart and the loss of the road led to initial problems in accessing education and medical facilities as well as obtaining basic foodstuffs. In addition to the obvious physical problems, an increase in mental health issues has been reported after this and other geographical catastrophes (Ashraf *et al.* 2012). Among those affected in the Hunza Valley there were several distinct ethnic groups each with different languages. Politically, therefore, the repercussions have been serious at all levels. The landslide occurred in a remote region of Pakistan that had been used to receiving Federal Government support, but recovery required a higher level of assistance, and this had to be organised through the cooperation of NGOs, and other bodies including national and local government. Many families received only a small financial settlement and were left to organise their own relocation and rebuilding. Predictably, local satisfaction with the measures taken and support received has not always been great (Iqbal *et al.* 2014). In occurrences such as this, many local people feel that their own experience and action provides more significant mitigation measures than the reality of the help offered by outside agencies, and, in addition, access to outside aid supplying medical and other resources can be limited (Ashraf *et al.* 2012).

Given the economic importance of the Hunza Valley as a major trade route between Pakistan and China, the potential economic consequences of the loss of the highway were far reaching, extending well beyond the local community. Initially road communication was halted, and, even by 2014, traffic was reported as running at less than a quarter of its original level. In the autumn of 2015 an international cooperative effort resulted in the construction of four tunnels re-routing the highway along the southern shores of the lake. Of course, the impact on international trade has to be measured alongside that on the local economy as the passage of all goods along the valley, including local produce, was impacted. This is also a tourist route with all the concomitant advantages and disadvantages that tourism brings alongside its demands. The benefits of the tourist-dollar come with stringent requirements for infrastructure and safety that are often outside the normal experience of local communities. While the creation of the lake has, of itself, become something of an attraction, the needs of visitors for specific foods, enhanced consumption of fresh water, functioning digital connections, efficient transport and personal safety, all create pressures, especially in a tectonically active area that is still struggling to regain sustainability after a natural catastrophe.

It should also be noted that the long term environmental consequences of the landslide will play into the changing way of life here for many years to come. Over and above the initial destruction of the ecosystem under the landslide and lake, there was the drying up of a stretch of the Hunza River running around 100 km downstream with resultant impact on species there. In general, soils in the area are less stable since the event and sedimentation has changed dramatically. In addition, long term monitoring is now necessary relating to the stability of the natural dam that holds back the lake and of the spillway that controls the water level (Iqbal *et al.* 2014). Prevention of further destruction is a priority.

The recreation of daily life in the Hunza Valley has not been a straightforward matter of reconstruction. The relocation of houses and settlements is a difficult issue, the rebuilding of mental and emotional stability is long-term and specialist, and total preservation of the social infrastructure that existed prior to the landslide is unlikely. The scale of the disaster is very different from that at Dunwich, but overall the consequences for the local population may not be that dissimilar.

Nunalleq

Along the eastern shores of the Bering Sea, rising relative sea-levels and melting permafrost due to global warming are having an impact on the coast. In the Yukon-Kuskokwim Delta region, settlements are already retreating from the sea and communities are increasingly aware of the fragility of their environment. A joint project of survey and excavation led by the village corporation of Qanirtuuq Inc., and the Yup'ik Eskimo village of Quinhagak together with the University of Aberdeen is investigating the remains of a village named Nunalleq (meaning 'Old Village' in Yup'ik) a pre-contact Eskimo settlement dating to AD 1300–1650 (Knecht 2014). The work is highly specialised, but it is an important project if the traces of the earlier communities who called this stretch of the Arctic home, are not to be lost (Fig. 13.3). Knowledge transfer is a significant part of the process: while the Aberdeen team can teach the local community much about the recording, recovery, analysis and conservation of the material they are finding; the community members of the project have as much to offer the archaeologists in terms of interpretation, local production skills, environmental understanding, stories, and histories.

The Nunalleq site lies on the shore, exposed to the elements. Sea and storms here combine into a highly erosive force and the archaeologists recorded 10–15 m of lateral erosion between 2009 and 2014. The finds, nevertheless, are spectacular and provide a remarkably intimate view of life and society. At present the conditions mean that organic material survives in near mint condition: traces of the original turf houses preserve wooden floor levels; while soils contain plant remains, feathers, fur, and insects. The inventory of materials includes wood, basketry, matting, cordage, human hair, stone and animal bone (Forbes *et al.* 2015). Many composite artefacts, of the sort only dreamed of on conventional archaeological sites elsewhere, have been recovered. While the scope for standard archaeological techniques is great, this is much more than a straightforward field project. The people of Quinhagak are only too aware of the impacts of the changing world on their lives. In addition to the vulnerability of daily life as it is experienced today, they recognise the threat to past knowledge and

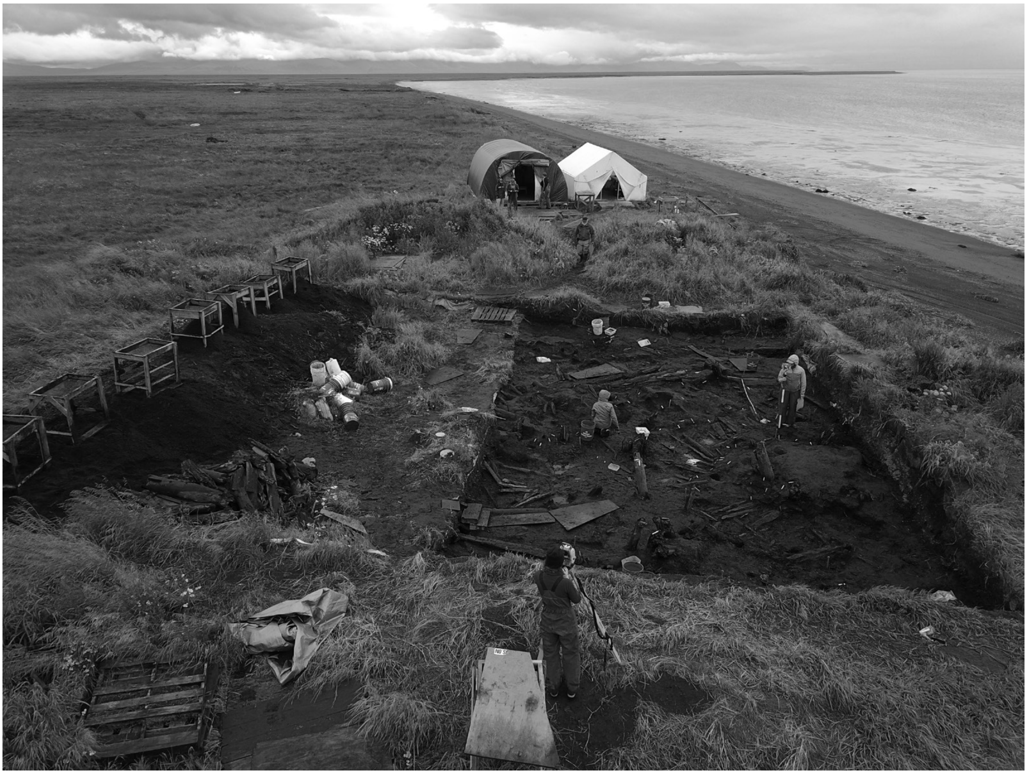


Fig. 13.3 This view of the site at Nunalleq gives a good idea of its vulnerable situation on the edge of the Bering Sea. The richly preserved timber remains may also be seen. Image: Rick Knecht, University of Aberdeen

understanding as the remains of the ancient settlement are exposed and eroded. The Nunalleq project is an attempt to recover and record this information before it is lost for ever. It is an important step for the local community whose traditional belief systems teach that the ancient settlement sites should be left undisturbed. Ancestral wisdom is central to the Yup'ik and by retrieving the artefacts and information the community elders hope to reinforce the roles of traditional cultural ways and values especially among the younger generation. Already the finds being derived from the project are starting to play an important role in community social life.

The archaeological material is temporarily removed to the UK for analysis, but everything will be returned to Alaska where it will form the heart of the new Nunalleq Culture and Archaeology Centre, scheduled to open in 2018. Although this is very much an ongoing project it plays a significant part in the way in which the community is adapting to the new circumstances created by global warming. Theirs is, at present, a slower change than those of the previous examples, but the destruction to twenty-first century life caused by coastal and environmental change here in Alaska is no less significant. Like their fellow communities around the world they have had to develop their own priorities and find the ways in which to build it into their everyday reality. Like others, they have had to come to terms with the fact that this is not just the physical loss of goods and houses, but also the intangible loss of their heritage in terms of knowledge and histories. The impact is not just material, but also emotional.

As a side effect of the project Knecht and his team plan to develop guidelines for others in similar situations wishing to rescue eroding archaeology from rising sea-levels in northern environments (Knecht 2014; Ledger *et al.* 2016). In the Yup'ik area alone there are many instances of archaeological remains becoming exposed along the fragile shore and this is a situation familiar to all who live in northern coastal regions.

Prehistoric Orkney

The history of relative sea-level change in Orkney in the Early Holocene makes it clear that the existing record of Mesolithic and Neolithic archaeology is incomplete because of the failure of contemporary archaeology to take into account the submerged landscape around the islands. This is not just a question of the dearth of sites recorded in the underwater zone. It also touches on wider landscapes, the human experience in the islands, and access to resources. While few Mesolithic sites have been recorded in the islands, and little Mesolithic research has been undertaken, the picture of Neolithic Orkney is more advanced. Landscape submergence throughout the Holocene is likely to account for the paucity of Mesolithic sites, many of which may have lain near to the ancient coasts, but it is now possible to understand the archaeology of Neolithic Orkney in a more holistic way.

Landscape change at key sites such as Skara Brae and Pool, where the erosion of coastal barriers led to dramatic alterations in local topography, has long been noted. The changing shorelines and topography had an impact on local resources and lifestyles, helping to make farming more difficult with the increasing occurrence of salt and sand blow on to the fields. At Skara Brae, the inhabitants were, apparently, finally driven to roof over the passages between houses. The iconic 'semi-subterranean' image of Skara Brae, which ranged in past interpretations from the clever design of highly specialised northern villagers to the primitive underground dwellings of cosy prehistoric simpletons, are more likely, in fact, to be the last resort of a community trying to cope with the harsh realities of coastal change, (Shepherd 2016).

At the heart of Neolithic Orkney, the dynamic landscape (Fig. 13.4) which formed the background to significant sites such as the Ness of Brodgar, Barnhouse, the Stones of Stenness and the Ring of Brodgar, was subject to ongoing transformation throughout the life of these monuments (Bates *et al.* 2016). It is not hard to consider that the prolonged rise of relative sea-level here, and the subsequent narrowing of the peninsula on which these sites were built, had a dramatic impact on those who used the sites (Wickham-Jones *et al.* 2016). As the peninsula diminished to half its original width, the encroachment of water upon the land must have been visible to those who built and used the sites. Local

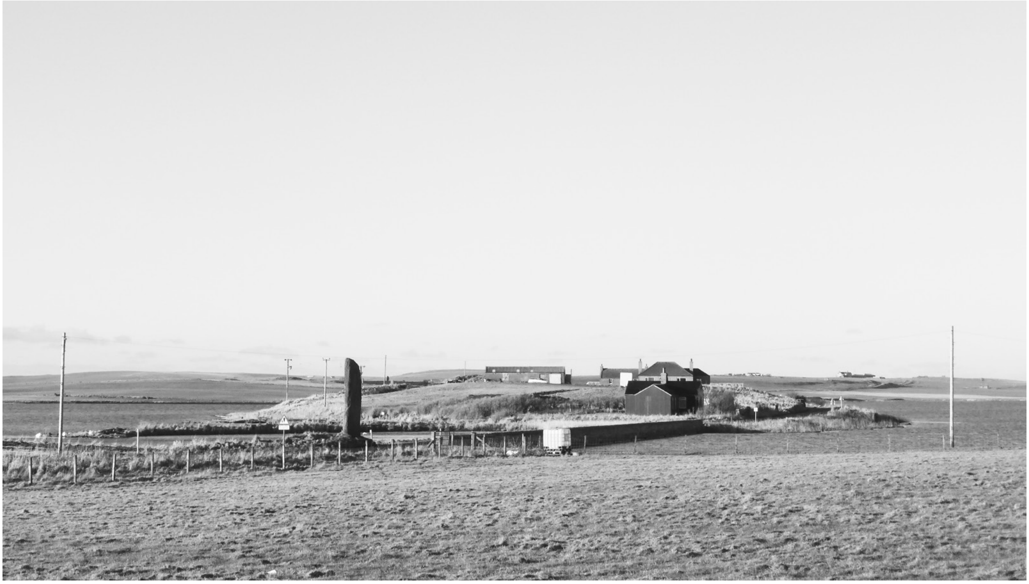


Fig. 13.4 The landscape at the Heart of Neolithic Orkney as it is today. The focus of Neolithic sites along this narrow stretch of land is remarkable. The single standing stone, the Watchstone, may be seen in the foreground and other monuments lie further along the isthmus. When these sites were first built this neck of land would have been as much as twice as wide and those who lived and worked here would have been very aware of the gradually rising sea-levels that slowly encroached on the land. It is hard not to imagine that they placed their monuments here in a deliberate act of defiance, or, perhaps, propitiation

sources of stone, from which material could be drawn for the monuments they focussed on, disappeared under the waves. Farmland along the shores of the lochs changed in nature. Evidence elsewhere suggests that the farmers of Neolithic Britain may have had a more complex relationship with the sea than their Mesolithic predecessors (Schulting *et al.* 2004; Montgomery *et al.* 2013). In Neolithic Orkney this relationship would have been at its most fragile. This was surely a significant factor contributing to social change that may have even prompted a physical response, given our increasing awareness of the seemingly escalating scale of events in Late Neolithic Orkney (Card 2018). Emerging interpretations suggest catastrophic cultural and possibly social change as society here moved into the Bronze Age (Card *et al.* 2017). Consideration of past relative sea-level rise and of the submerged landscape, allows us to consider the communities of Neolithic Orkney as they interacted with the world around them.

Conclusions

The study of the submerged landscapes and sites of the world certainly has much to offer archaeology in general, but it is so much more than a straightforward archaeological technique. The seabed may be the last part of the globe to receive archaeological attention, but, as we unlock the information preserved here, so we are accessing the ancient wisdom from so many communities whose remains have been cast adrift from dry land as we know it. Information relating to the movement of early hominin groups out of Africa, information relating to those who learnt to survive in different climates and environments from their homelands, information from communities which had to adapt to local landscape change during times of flood and inundation, and information from those whose world, while different geographically from our own, was, for long periods, no less stable. All have something to tell us. All help us to understand ourselves.

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